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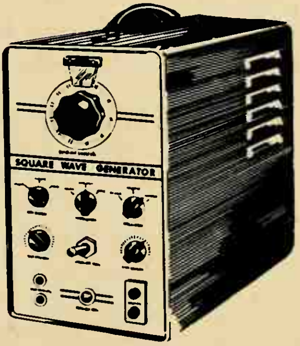
101 WAYS

to Use Your

SQUARE WAVE and PULSE GENERATORS



by Robert G. Middleton

101 ways to use your SQUARE-WAVE AND PULSE GENERATORS

by ROBERT G. MIDDLETON

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PREFACE

Square-wave and pulse generators are basic test instruments that provide very useful and often unique data in troubleshooting procedures. However, they are not as simple as signal generators and audio oscillators. For this reason, there has sometimes been more or less uncertainty among technicians concerning square-wave and pulse procedures. *101 Ways To Use Your Square-Wave and Pulse Generators* explains proper procedures, and is intended to show you how to get the most out of your square-wave and pulse generators.

With the present-day trend toward packaged printed circuits, square-wave and pulse testing has taken on practical importance that could scarcely have been foreseen. In the past, it was always possible to disconnect a capacitor, coil, resistor, or other component in order to make tests with an ohmmeter, capacitor checker, or other conventional test instrument. Today, however, we must contend with comparatively expensive packaged printed circuits in which the individual components cannot be disconnected for testing. This circumstance places the more familiar and conventional test instruments at a serious disadvantage.

Square-wave and pulse generators provide informative tests, using some or all of the terminals provided on a packaged printed circuit. There are two general ways of evaluating test results. The easiest is a comparison test. However, comparison tests are often impractical. Therefore, we must often turn to waveform analysis. This is a very extensive subject. However, the basic principles of waveform analysis are not difficult. In this book, these basic principles are explained and illustrated for typical practical situations encountered at the bench.

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Square-wave and pulse generators provide informative tests using some or all of the terminals provided on a packaged printed circuit. There are two general ways of evaluating test results. The easiest is a comparison test. However, comparison tests are often impractical. Therefore, we must often turn to waveform analysis. This is a very extensive subject. However, the basic principles of waveform analysis are not difficult. In this book, these basic principles are explained and illustrated for typical practical situations encountered at the bench.

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INTRODUCTION

A square-wave or pulse generator supplies an output voltage which is effectively switched on and off at regular intervals. Fig. I-1 shows the appearance of a square wave displayed on a scope screen. A square wave or pulse is considered to be built up from a large number (theoretically an infinite number) of sine waves. Figs. I-2 and I-3 depict a partial build-up of a square wave and a pulse from sine waves The sine waves are harmonically related—each of the sine-wave components is an odd harmonic of the fundamental frequency in a square wave. The repetition rate of the square wave is equal to the fundamental frequency. In a perfect square wave, the fundamental and harmonics all go through zero simultaneously; or, all of the waveform components are in phase. Out-of-phase components produce a pulse.

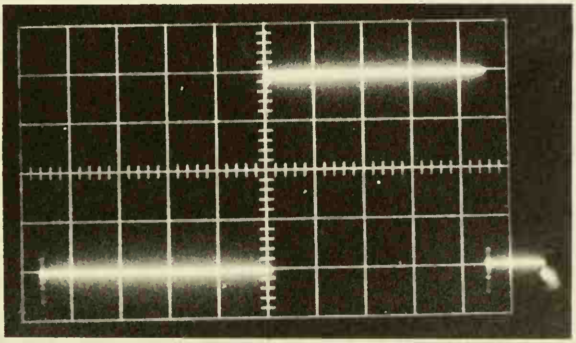


Fig. I-1. Square wave displayed on scope screen.

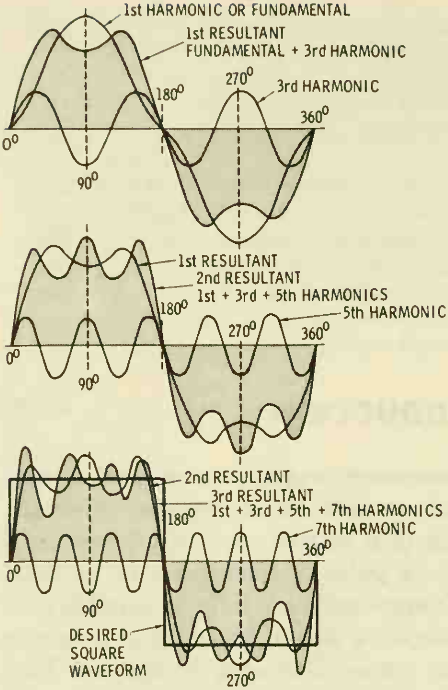


Fig. I-2. A square wave is considered to be many sine waves.

An ideal square wave or pulse would rise and fall in zero time. However, in practice this is not true, as depicted in Fig. I-4. Measurement of rise time (or fall time) is an important procedure in square-wave and pulse tests. This measurement is easily made with a triggered-sweep scope that has a calibrated time base. Just as a square-wave or pulse generator cannot supply a waveform that rises and falls in zero time, neither can a scope respond to a suddenly applied voltage in zero time. The better the generator and scope, the faster is the displayed rise of the square wave or pulse.

As shown in Fig. I-5, a pulse has stronger harmonics than a square wave. The narrower the pulse, the stronger the harmonics are. This fact makes square-wave generators and pulse generators suitable for different types of tests. As would be anticipated, a fast-rise waveform has stronger harmonics than a slow-rise waveform, as depicted in Fig. I-6. When a low-frequency test is involved, such as a test of an RC integrator, a square-wave generator is more useful than a pulse generator. On the other hand, when a high-frequency test is involved, such as a test of

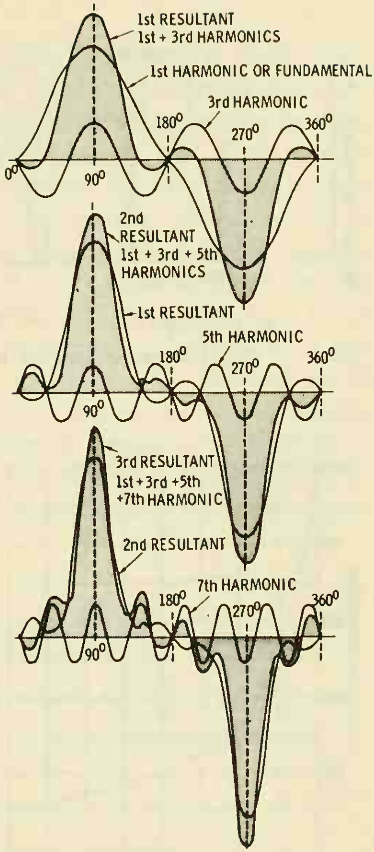


Fig. 1-3. A pulse is considered to be formed from many sine waves.

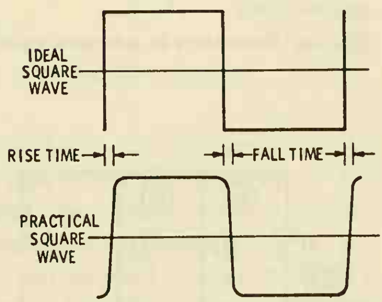
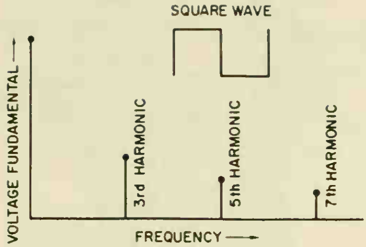
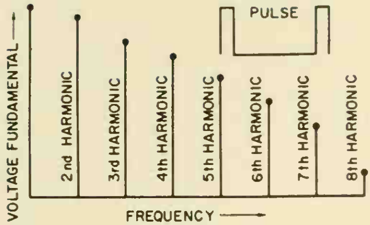


Fig. 1-4. Rise and fall times are not instantaneous.

a small coil or an IF transformer, the pulse generator is more useful. This is not to say that either generator cannot be used—however, it is comparatively difficult to obtain substantial out-

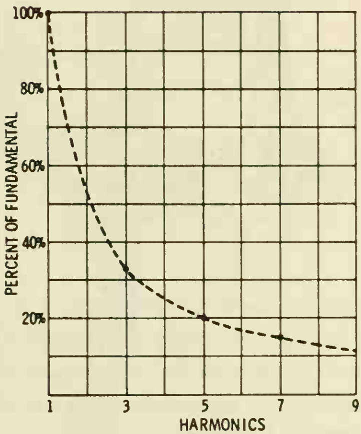


(A) Square wave.

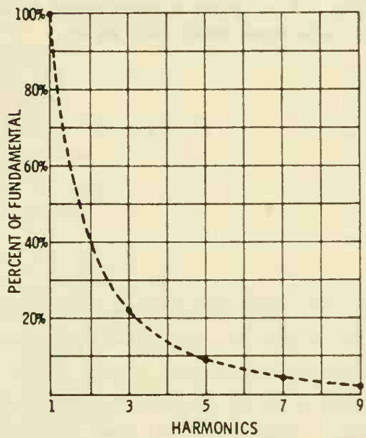


(B) Pulse waveform.

Fig. 1-5. Harmonics of a square wave versus a pulse.

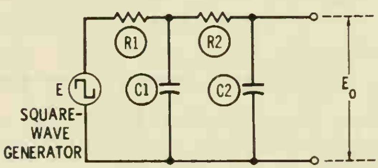


(A) Harmonic amplitudes in an ideal square wave.

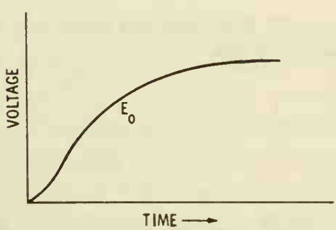


(B) Harmonic amplitudes with a slow rise.

Fig. 1-6. Harmonics in a square wave are weakened when the rise time is slow.



(A) A two-section RC integrator.



(B) Output waveform.

Fig. 1-7. Rise time of an output waveform.

put from an integrator when a pulse generator is used. Conversely, it is comparatively difficult to obtain substantial output from an IF transformer when a square-wave generator is used.

All circuits and sections in a TV receiver (or other device) have a certain rise time. Fig. I-7B depicts the rise of the output waveform from a two-section RC integrator. Measurement of rise time is a basic test procedure, because a defective component changes the rise time. Thus, if C1 is open in Fig. I-7A, the waveform will rise faster than normal. The rise time of a waveform is defined as the number of seconds (or fraction of a second) required for the waveform to rise to 63 percent of its maximum amplitude. In the case of a simple RC series circuit, the rise time is equal to the number of seconds (or fraction of a second) corresponding to one time constant, where the time constant is equal to RC seconds, R being in ohms and C in farads. (See Fig. I-8).

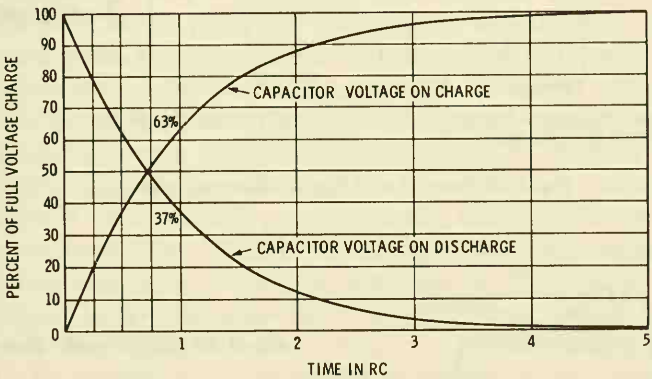


Fig. I-8. A universal RC time-constant chart.

Of course, the chart shown in Fig. I-8 is not applicable to the circuit shown in Fig. I-7, because this is not a simple series RC circuit. However, we will find that there are other universal charts which are applicable to circuits such as shown in Fig. I-7. Observe that the curves in Fig. I-8 correspond to distortion of a square wave by a differentiating or integrating circuit. Various basic square-wave and pulse distortions are shown in Figs. I-9 to I-11. Note that phase shift changes the shape of a reproduced square wave, and that frequency discrimination changes the

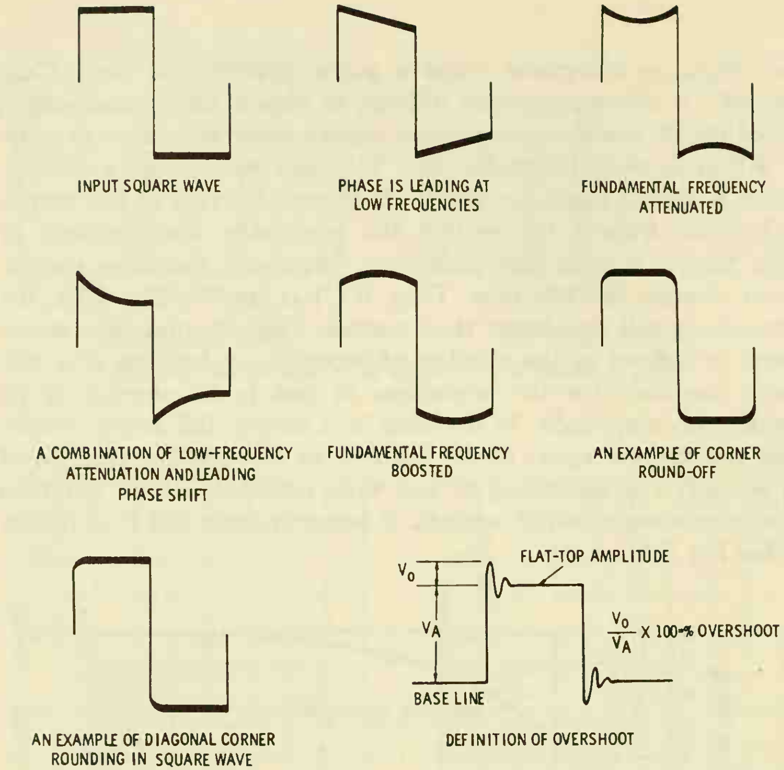


Fig. 1-9. Some basic square-wave distortions.

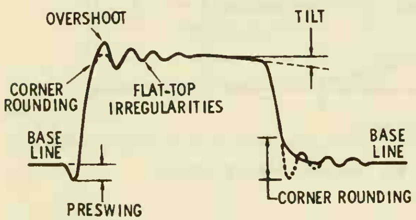


Fig. 1-10. Basic pulse distortions.

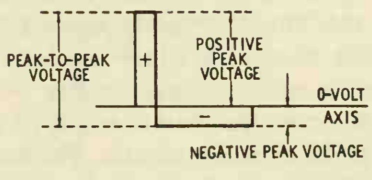


Fig. 1-11. Voltages of a pulse waveform.

shape of a reproduced square wave. Fig. I-12 shows the terminology used for discussing square waves.

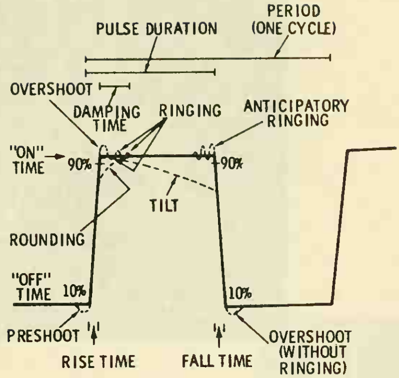
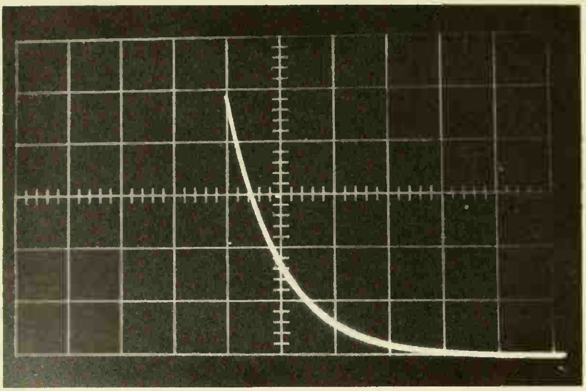


Fig. I-12. Terminology of the square wave.

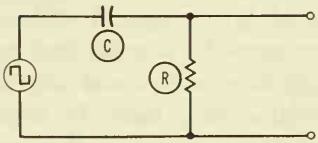
Considerable square-wave and pulse test work can be accomplished with an ordinary service-type scope. A wide-band scope, with response out to 4 or 5 mc, provides a great deal more utility. The chief limitation of an ordinary wide-band service scope is that it does not have a calibrated time base. In turn, rise-time measurement is not practical. Since many of the basic square-wave and pulse tests require measurement of rise time, a lab-type scope with calibrated sweeps is quite desirable. All scopes with calibrated time bases also have triggered-sweep action.

A triggered-sweep scope utilizes a graticule marked off in centimeter intervals (see Fig. I-13A). The time-base controls are calibrated in microseconds per centimeter, milliseconds per centimeter, or seconds per centimeter. In turn, the elapsed time between two successive horizontal intervals in Fig. I-13A can be determined merely by glancing at the time-base setting. In this example, the output waveform from the differentiating circuit falls to 37 percent of its maximum amplitude in one horizontal interval. Therefore, the time constant of the RC circuit is given by the time-base setting.

Triggered-sweep scopes with ample performance for shop tests are available in kit form at reasonable cost. Square-wave generators with satisfactorily fast rise are also available in kit form. In general, the square-wave or pulse generator need not have a faster rise time than the scope to be used with it. The reason, of course, is that if a scope has a rise time of 0.08 microsecond, for example, it would be unavailing to use a square-wave generator with a 0.02-microsecond rise. The scope could not respond to a rise faster than 0.08 microsecond. Hence, it is most economical



(A) Scope display.



(B) RC circuit.

Fig. 1-13. Response of an RC differentiating circuit.

to choose a square-wave (or pulse) generator and scope that have approximately the same rise times.

The 101 tests described in this book have been selected to illustrate the more fundamental types of square-wave and pulse test methods, and to outline the general range of applications for these instruments. However, many of the more sophisticated applications, such as semiconductor testing, spectrum analysis, and time-domain reflectometry, cannot be covered in a book of limited size. The intent of the book is to provide a practical working knowledge which will be of maximum utility to technicians, both in the shop and in the factory.

EQUIPMENT TESTS

U1

To Measure the Rise Time of a Square-Wave or Pulse Generator

Equipment: Oscilloscope with calibrated sweeps and a comparatively fast rise.

Connections Required: Connect the output signal from the square-wave or pulse generator to the vertical-input terminals of the scope, as shown in Fig. 1.

Procedure: Adjust the scope controls to expand the leading edge of the square wave or pulse, as depicted in Fig. 2. Set the repetition rate of the generator sufficiently high so that the pattern is not dim; on the other hand, the repetition rate must not be set so high that the leading edge does not attain normal amplitude (this precaution applies particularly to some pulse generators).

Evaluation of Results: The rise time of the square wave is equal to the elapsed time between the 10 percent and 90 percent of maximum points on the leading edge. (See Fig. 3.) Note that unless it is known that the scope has a faster rise time than the generator, the test result can depict either the rise time of the scope or of the generator.

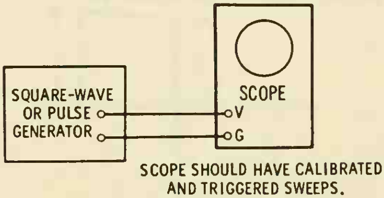


Fig. 1. Test setup for measuring rise time.

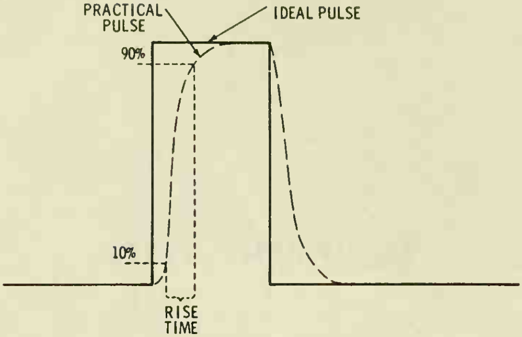


Fig. 2. Rise time of ideal and practical pulses.

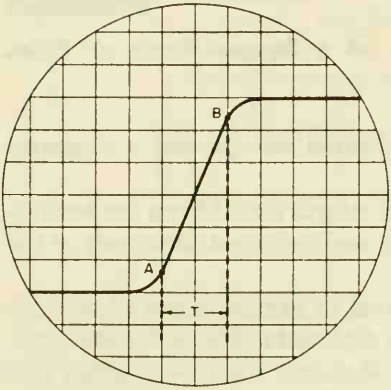


Fig. 3. Measurement of slope rise time.

NOTE 1

Displayed Rise Time

When the rise time of a generator and scope are in the same general range, the rise time of the displayed square waveform depends on both rise times. The rise time of the displayed square waveform is:

$$T_r = \sqrt{T_{rg}^2 + T_{rs}^2}$$

where,

T_r is the displayed rise time,
T_{rg} is the rise time of the generator,
T_{rs} is the rise time of the scope.

To Measure the Low-Frequency Cutoff Point of an AC Scope

Equipment: Scope to be tested and square-wave generator.

Connections Required: Connect the output from the square-wave generator to the vertical input terminals of the scope, as depicted in Fig. 4.

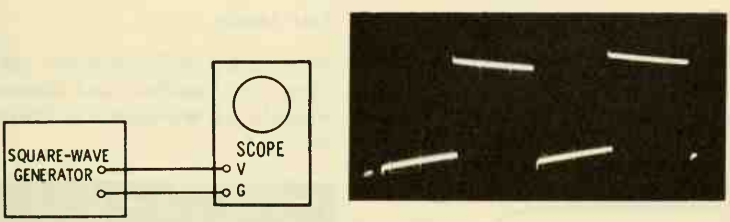
Procedure: Reduce the repetition rate of the square-wave generator until there is from 10 to 15 percent tilt on the top of the square wave, as shown in Fig. 5. (The exact percentage of tilt is not critical, but its exact percentage must be measured on the scope screen.) In other words, measure E_1 and E_2 carefully.

Evaluation of Results: The low-frequency cutoff point of the scope's vertical amplifier occurs at the point where the response is 3 db down. This cutoff frequency is called f_c. Note that:

$$f_c = \frac{2f\,(E_2 - E_1)}{3\,(E_2 + E_1)}$$

where,

f_c is the frequency of cutoff,
f is the square-wave frequency,
E_2 and E_1 are the amplitudes shown in Fig. 5.



(A) Test setup. (B) Tilted square wave.

Fig. 4. Check of scope response at low frequencies.

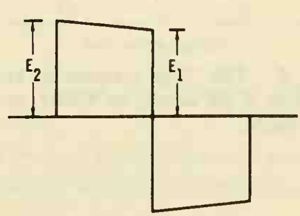


Fig. 5. E_1 equals 0.9 E_2 in the tilted wave, or there is 10 percent tilt.

To Measure the High-Frequency Cutoff Point of an AC Scope

Equipment: Scope to be tested and square-wave or pulse generator that is known to have a considerably faster rise time than the scope.

Connections Required: Connections are made as shown in Fig. 1.

Procedure: Measure the rise time of the scope's vertical amplifier, as explained in U1.

Evaluation of Results: The rise time of the scope is related to its high-frequency cutoff point as follows:

$$f_c = \frac{0.35}{\text{Rise Time}}$$

The high-frequency cutoff point of the vertical amplifier occurs at the point where the response is down 3 db. (See Fig. 6.) Here is a practical example of f_c calculation versus rise time; if the rise time of the reproduced square wave is 0.088 microsecond, then f_c is equal to 0.35/0.088, or 4 mc approximately.

NOTE 2

Avoid Long Test Leads

When working with fast-rise square waves or pulses, avoid the use of long test leads. A pair of long test leads operates as a transmission line or resonant stub. In turn, the test setup will oscillate and distort the reproduced waveform as illustrated in Fig. 7.

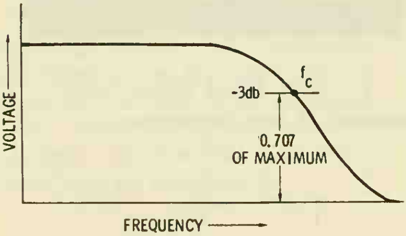


Fig. 6. The high-frequency cutoff point is 3 db down, or 0.707 of the maximum.

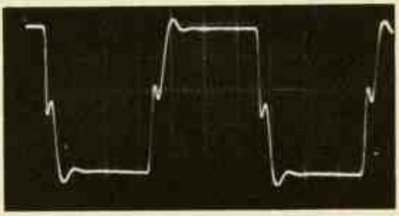


Fig. 7. Ringing of the waveform caused by long test leads from the oscilloscope.

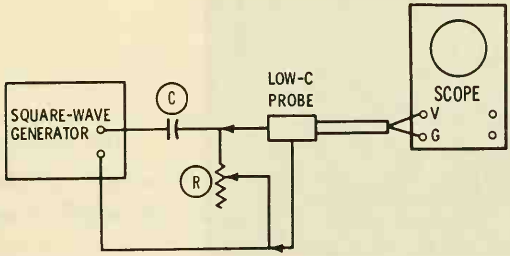
To Measure the Rise Time of a Square Wave With an RC Circuit

Equipment: Square-wave generator to be tested, fixed capacitor, potentiometer, and scope that is known to have a faster rise time than the square-wave generator. This method is an expedient to be used when the scope does not have a calibrated time base.

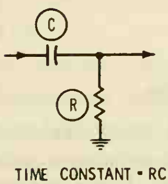
Connections Required: Connect the equipment as shown in Fig. 8A.

Procedure: Start with the potentiometer set to a comparatively high resistance so that the RC circuit operates as a coupling circuit. Note the amplitude of the reproduced square wave. Next, reduce the resistance of the potentiometer until the differentiated pulse has 65 percent of maximum amplitude.

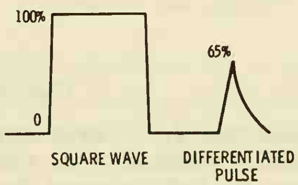
Evaluation of Results: Measure the resistance of the potentiometer. The resistance in ohms, multiplied by the capacitance value in farads, gives the approximate rise time of the square wave in seconds (actually, a small fraction of a second). For the most accurate results, the potentiometer should have a



(A) Test setup.



(B) Differentiating circuit.



(C) Pulsed amplitude is 65 percent.

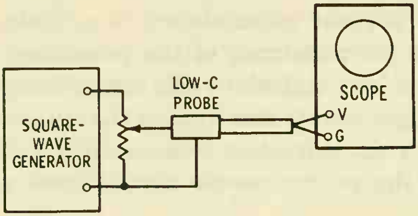
Fig. 8. Rise time of a square wave is approximately equal to the time constant of a differentiating circuit.

maximum resistance of not more than 1000 ohms; only a carbon potentiometer should be used. Select a value for C that produces only slight differentiation of the square wave in combination with 1000 ohms.

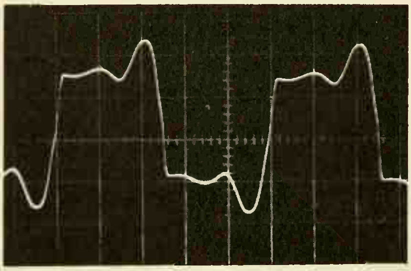
NOTE 3

Overshoot and Ringing

Fig. 9 shows why a wirewound potentiometer (or wirewound fixed resistor) is unsuitable for fast-rise square-wave tests. The output waveform displays overshoot and ringing. This response is caused by the inductance of the wirewound element resonating with the distributed capacitance and stray capacitance of the system.



(A) Test setup.



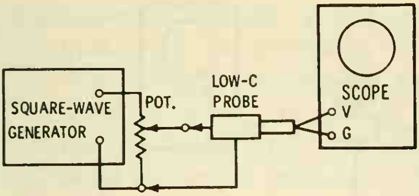
(B) Waveform.

Fig. 9. Square-wave response of a wirewound potentiometer.

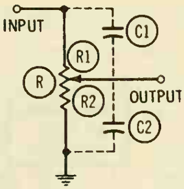
NOTE 4

High Resistance Distortion

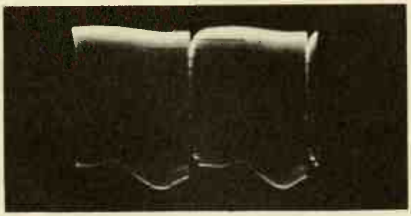
A potentiometer has distributed capacitance; therefore, if the potentiometer has high resistance, the capacitance becomes significant and distorts the output waveform at various settings. Fig. 10 shows typical square-wave distortion produced by a high-resistance potentiometer. Hence, only low-resistance potentiometers should be used to attenuate square waves.



(A) Test setup.



(B) Potentiometer R comprises R1-C1 and R2-C2.



(C) Typical output waveform.

Fig. 10. High-resistance carbon potentiometer distorts a square wave.

U5

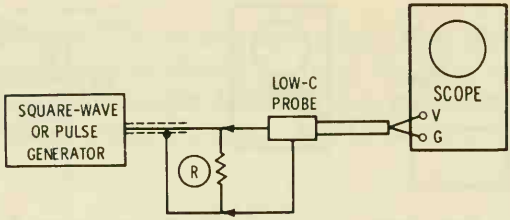
To Check for Proper Termination of an Output Cable for a Square-Wave or Pulse Generator

Equipment: Square-wave or pulse generator with output cable to be tested, and wide-band scope with low-capacitance probe.

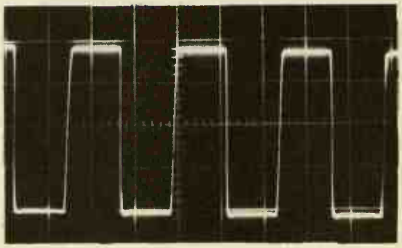
Connections Required: Connect the equipment as shown in Fig. 11A.

Procedure: Set the square-wave or pulse generator for a high repetition rate, and observe the pattern on the scope screen.

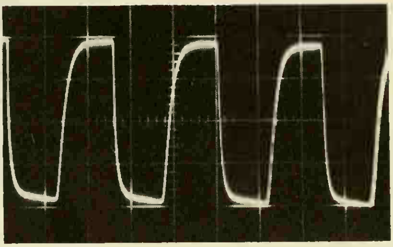
Evaluation of Results: When the correct value of R is used (Fig. 11A) to terminate the cable, minimum distortion of the square wave or pulse occurs. The test should be made with a low-C probe to avoid distortion from excessive shunt capacitance across R by the scope-input system.



(A) Test setup.



(B) 1-mc square-wave output, proper termination by R.



(C) 1-mc square-wave output, unterminated cable.

Fig. 11. Proper termination of an output cable.

U6

To Check the Repetition Rate of a Square-Wave or Pulse Generator

Equipment: Square-wave or pulse generator to be calibrated, crystal oscillator with suitable quartz crystals, and scope with triggered sweep.

Connections Required: Connect the outputs from the generator and the crystal oscillator alternately to the vertical-input cable of the scope, as depicted in Fig. 12.

Procedure: Operate the crystal oscillator with a quartz crystal that has a frequency equal to the repetition rate to be checked, or on a frequency which is a multiple or submultiple of the repetition rate to be checked. Then set the square-wave or pulse generator to this repetition rate for comparison of patterns on the scope screen.

Evaluation of Results: If the quartz crystal has the same frequency as the repetition rate to be checked, the patterns will normally occupy the same horizontal interval on the scope screen. If the crystal has a frequency that is double the repetition rate, two cycles will normally occupy the same horizontal interval as the square wave (or pulse). Or, if the crystal has a frequency that is half the repetition rate, two cycles of the square wave (or pulse) will normally occupy the same horizontal interval as the sine wave. In case the repetition rate of the square-wave or pulse generator is incorrect, adjust the maintenance controls as required.

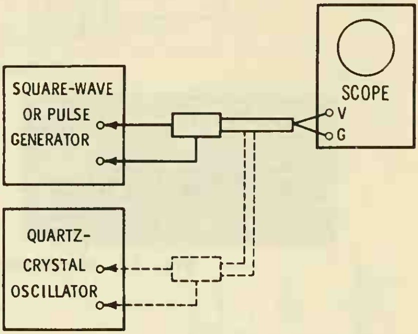


Fig. 12. Calibration of generator repetition rate.

U7

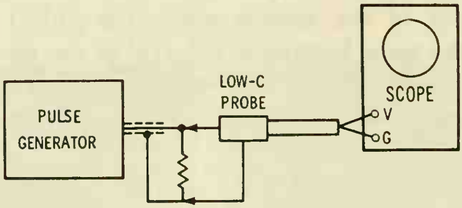
To Measure the Pulse Duration (Pulse Width) of the Output Waveform From a Pulse Generator

Equipment: Pulse generator to be tested and scope with triggered sweeps and calibrated time base.

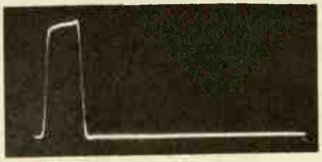
Connections Required: Connect the equipment as shown in Fig. 13A. If the sweep calibration of the scope needs to be checked, use the method explained in U8.

Procedure: Set the pulse generator to successive pulse widths, such as 0.1, 0.2, 0.5, 1, 10, 100, and 1000 microseconds, and measure the pulse widths as indicated by the time-base controls of the scope.

Evaluation of Results: If the measured width is greater or less than the rating on the generator (such as ±4 percent), adjust the pulse-width maintenance controls of the generator as required. These controls are located in the pulse-duration section of the generator. Fig. 14 shows a block diagram of a typical pulse generator.



(A) Test setup.



(B) Display of pulse at 0.2-microsecond pulse width.

Fig. 13. Measuring pulse duration.

NOTE 5

Flat-Top Maintenance Control

The pulse waveform shown in Fig. 13B has an upward tilt. Most pulse generators have a flat-top maintenance control, as seen in Fig. 14. This control should be adjusted to make the top of the pulse level. Sometimes the displayed pulse may show overshoot (or overshoot and ringing), as illustrated in Fig. 15. Overshoot can be controlled by means of a maintenance control called the overshoot adjustment (see Fig. 14). Ringing can be minimized by correct termination of the generator output cable.

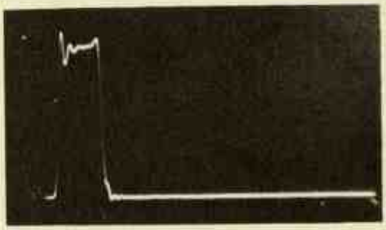
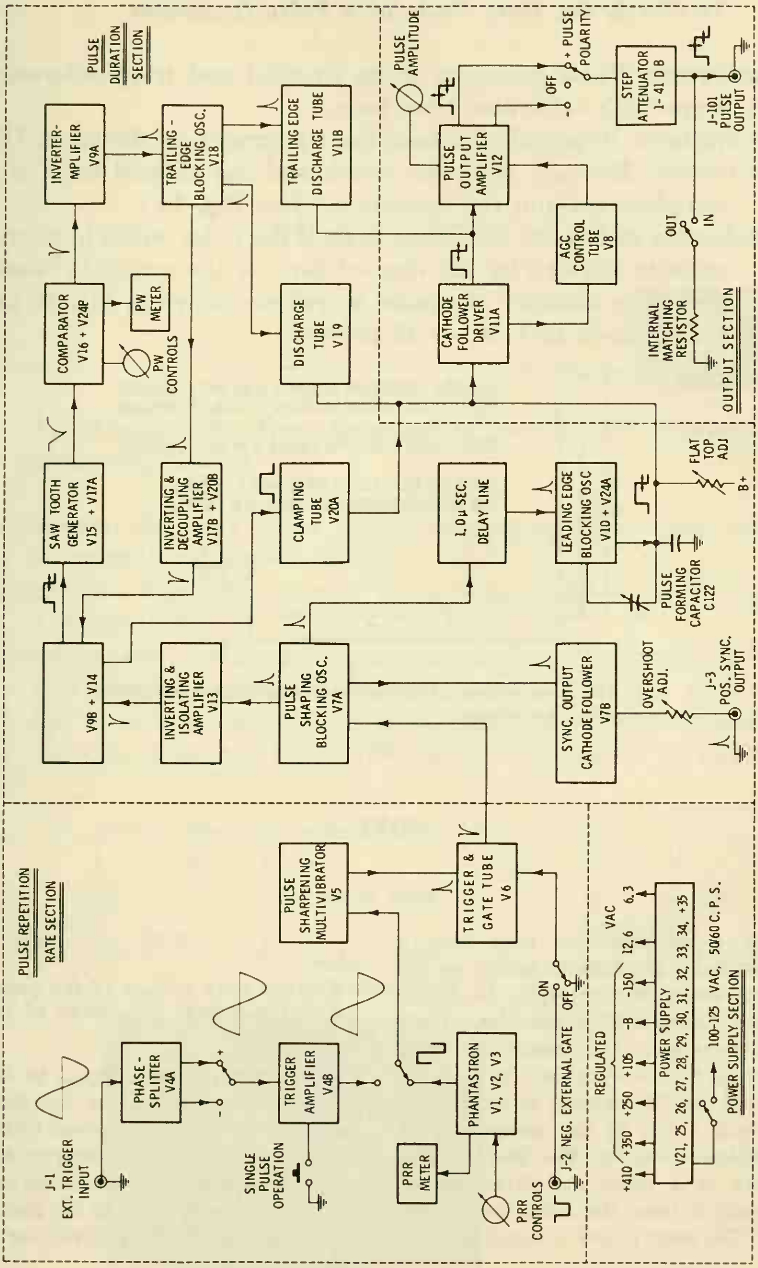


Fig. 15. Example of overshoot and ringing.



Courtesy Simpson Electric Co.

Fig. 14. Block diagram of a pulse generator.

To Check the Duty Cycle of a Pulse Generator

Equipment: Pulse generator to be checked and triggered-sweep scope with calibrated time base.

Connections Required: Connect the equipment as shown in U7.

Procedure: Measure the pulse width and the elapsed time of a complete cycle in the waveform. (See Fig. 16.)

Evaluation of Results: The duty cycle is the pulse width in microseconds, divided by the elapsed time of the complete waveform. For example, the pulse waveform shown in Fig. 16 has a duty cycle of 1/10, or 10 percent.

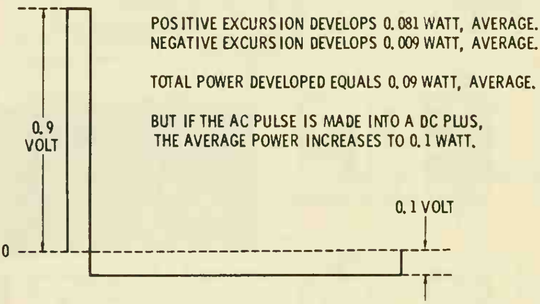


Fig. 16. Illustration of duty cycle and power relations in a pulse waveform.

NOTE 6

Duty Cycle

The pulse generator may have a maximum permissible rating on the duty cycle. For example, the maximum rating is 25 percent for a typical generator. The maximum rating should not be exceeded, in order to avoid possible damage to the power-output tubes in the generator. An understanding of the power relations in a pulse waveform can be obtained from the notations in Fig. 16. The peak power is equal to:

$$E^2/R$$

where,

E is the peak voltage of the pulse,
R is the output impedance of the generator.

The average power is equal to the peak power multiplied by the duty cycle. Neither the peak-power rating nor the average-power rating on the tubes in the generator should be exceeded. This is the basis of the maximum permissible duty cycle for a pulse generator.

RC CIRCUITS

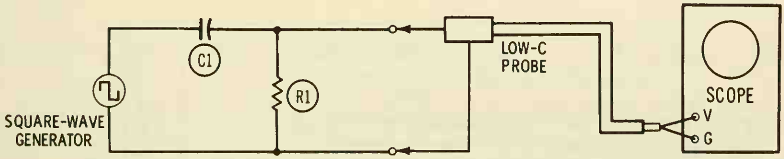
U9

To Measure the Time Constant of an RC Differentiating or Integrating Circuit

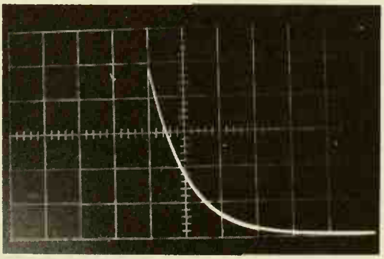
Equipment: RC unit to be tested, square-wave generator, and scope with calibrated sweeps.

Connections Required: Connect the equipment as shown in Figs. 17A and 18A.

Procedure: Set the square-wave generator to a repetition rate that permits display of practically the full leading edge of the waveform (about five or six time constants). Measure the time required for a differentiator waveform to fall to



(A) Test setup.

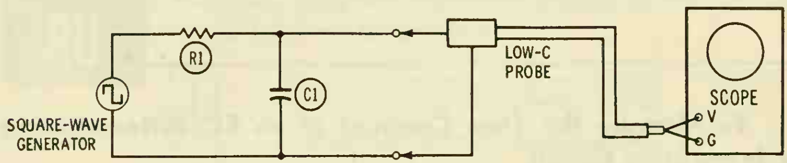


(B) Waveform.

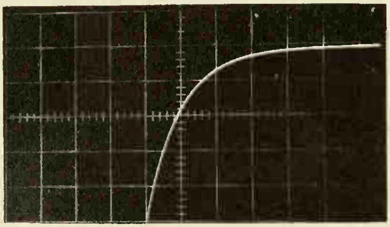
Fig. 17. Response of an RC differentiating circuit.

37 percent of its maximum amplitude; measure the time required for an integrator waveform to rise to 67 percent of its maximum amplitude.

Evaluation of Results: If the capacitor and resistor have normal values and if the capacitor is not leaking seriously, the time noted above will be equal to the product of the capacitance in farads and the resistance in ohms, the answer being in seconds. A universal RC time-constant chart is shown in Fig. 19B.

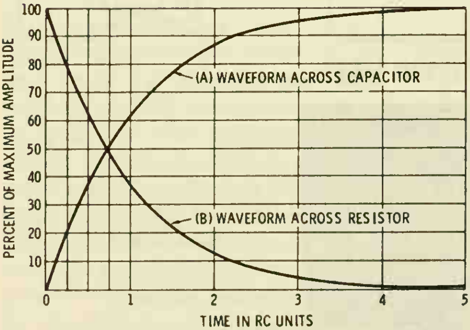


(A) Test setup.

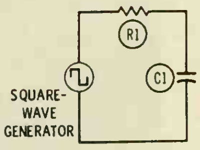


(B) Waveform.

Fig. 18. Response of an RC integrating circuit.



(A) Chart.



(B) RC circuit.

Fig. 19. Universal RC time-constant chart.

NOTE 7

Square Wave Versus Pulse Generator

A square-wave generator is most suitable for checking an integrator, or any arrangement that has a comparatively low frequency response. Either a square-wave or a pulse generator is suitable for checking a differentiator, or any arrangement that has a comparatively high frequency response. When testing circuits with a comparatively high frequency response at low repetition rates, a pulse generator with a very narrow pulse width is most suitable. The basic reasons are explained subsequently.

NOTE 8

Exponential Waveform

A simple differentiating or integrating circuit always has the same output waveshape, which is called an "exponential waveform." As the time constant of an RC differentiating circuit is varied, the output waveform changes in *aspect*, as depicted in Fig. 20. Note that if the vertical gain is advanced and the horizontal-sweep speed is reduced, curve No. 2 will coincide exactly with curve No. 1. Similarly, if the vertical gain is advanced still more and the sweep speed is reduced still more, curve No. 3 will coincide exactly with curve No. 1. In the case of an RC integrating circuit, the waveform aspect varies with the time constant, as illustrated in Fig. 21. This same variation in waveform aspect is seen if the time constant is fixed and the time-base setting is varied.

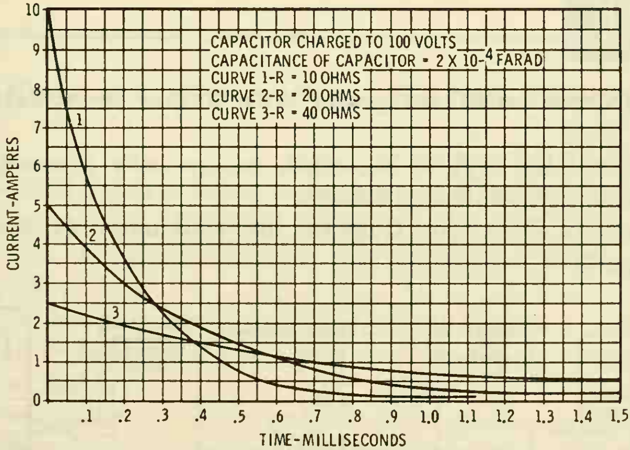


Fig. 20. The differentiated waveform has an aspect that depends on the time constant.

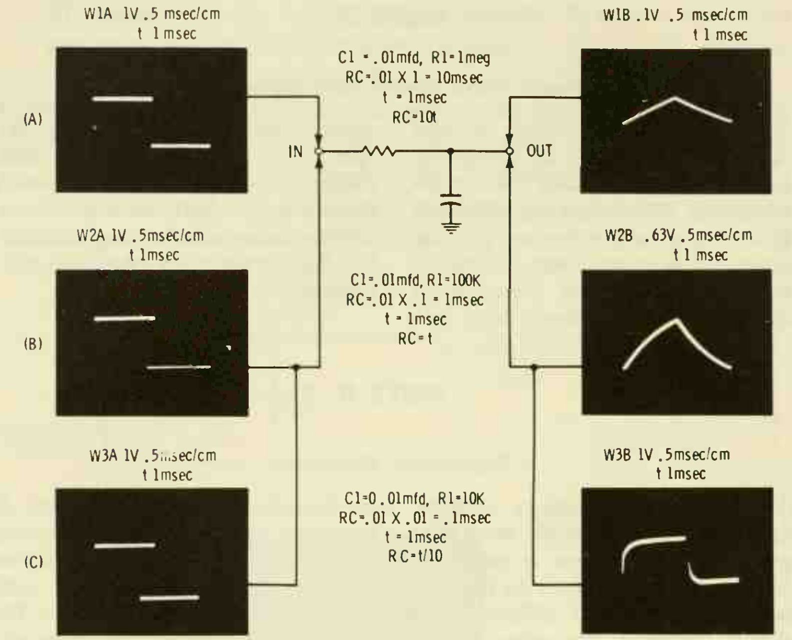


Fig. 21. Integrator output contains low-frequency elements of applied square wave.

U10

To Check an RC Integrator With Output Shunt Resistance

Equipment: RC unit to be tested, square-wave generator, and scope with calibrated sweeps.

Connections Required: Connect the equipment as shown in Fig. 22.

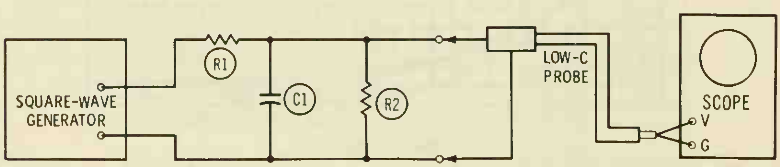


Fig. 22. Check of an RC integrator with a resistive load.

Procedure: Measure the time rise of the output square wave.

Evaluation of Results: An RC integrator with resistance shunted across the output is equivalent to a simple integrator in which C is the same, and R is equal to $R_1R_2/(R_1+R_2)$, as shown in Fig. 23. If the resistors and capacitors are normal in the RC unit, the measured rise time will be equal to the RC time constant of the equivalent circuit.

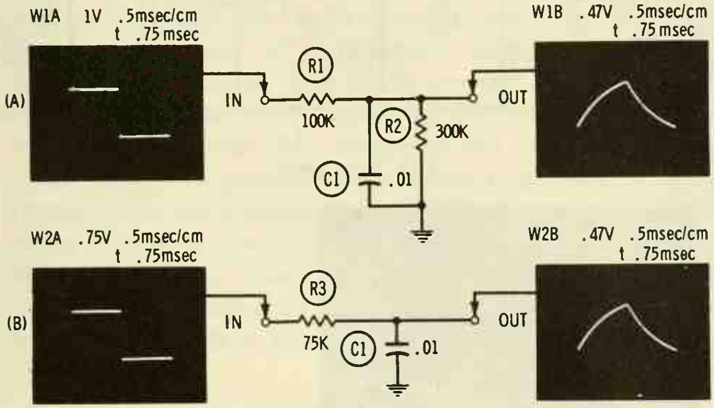


Fig. 23. Output waveforms prove circuit is an integrator equivalent.

U11

To Check a Two-Section Symmetrical RC Differentiating Circuit

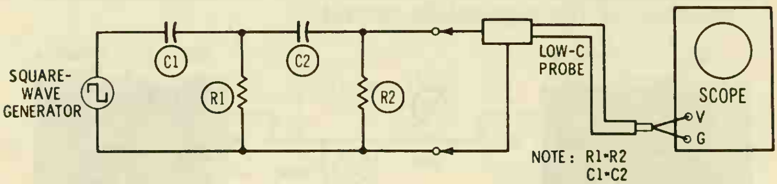
Equipment: RC unit to be tested, square-wave or pulse generator, and scope with calibrated sweeps.

Connections Required: Connect the equipment as shown in Fig. 24A.

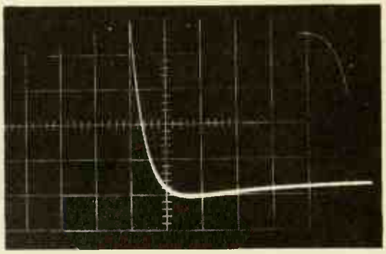
Procedure: Measure the elapsed time for the displayed waveform to fall from maximum to 5 percent of maximum (95 percent of the fall).

Evaluation of Results: If the resistors and capacitors are normal, the waveform will fall to 5 percent of maximum (95 percent of the fall) in approximately one time constant. The time

constant in seconds is equal to the product of the ohmic value of one of the resistors and the capacitance value of one of the capacitors in farads. A universal time-constant chart for the two-section symmetrical RC differentiator is shown in Fig. 25B.

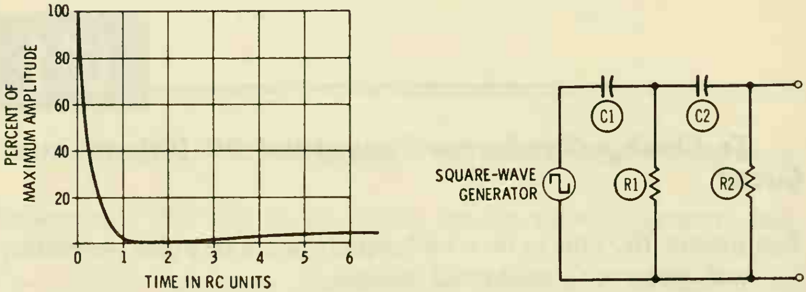


(A) Test setup.



(B) Waveform.

Fig. 24. Response of a two-section RC differentiating circuit.



(A) Chart. (B) Circuit.

Fig. 25. Universal RC time-constant chart for a two-section differentiating circuit.

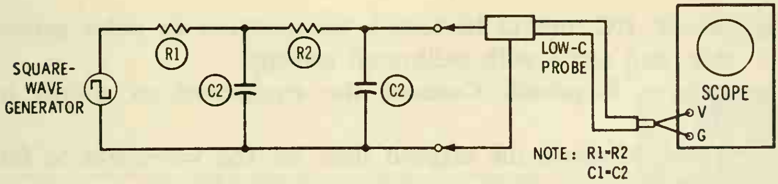
To Check a Two-Section Symmetrical RC Integrator

Equipment: RC unit to be tested, square-wave generator, and scope with calibrated sweeps.

Connections Required: Connect the equipment as shown in Fig. 26A.

Procedure: Set the square-wave generator to a repetition rate sufficiently low so that most of the leading edge of the waveform is displayed (9 or 10 time constants is sufficient). Measure the elapsed time to 63 percent of full amplitude.

Evaluation of Results: If the capacitors and resistors in the two-section symmetrical RC integrator are normal, the waveform rises to 63 percent of maximum amplitude in approximately three time constants, or 3RC, where R is the ohmic value of one of the resistors and C is the value of one of the capacitors in farads, the answer being in seconds. Fig. 27B depicts a universal RC time-constant chart for a two-section symmetrical integrating circuit.



(A) Test setup.

(B) Waveform.

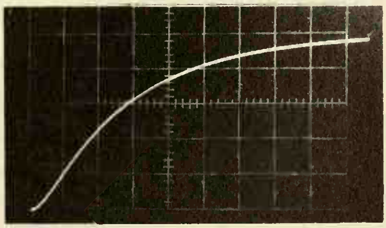
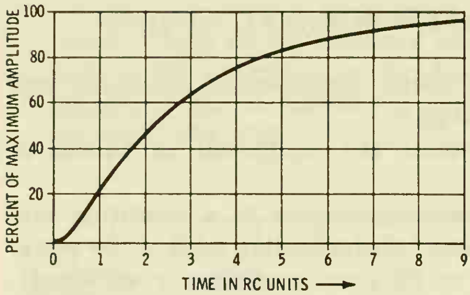
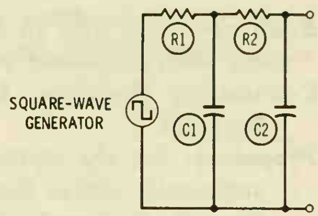


Fig. 26. Response of a two-section RC integrating circuit.



(A) Chart.



(B) Circuit.

Fig. 27. Universal RC time-constant chart for a three-section integrating circuit.

U13

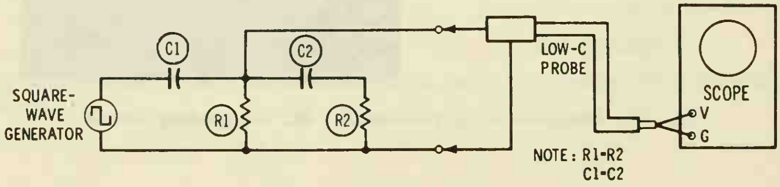
To Make a Midpoint Test of a Two-Section Symmetrical RC Differentiator

Equipment: RC unit to be tested, square-wave or pulse generator, and scope with calibrated sweeps.

Connections Required: Connect the equipment as shown in Fig. 28A.

Procedure: Measure the elapsed time for the waveform to fall to 30 percent of its maximum amplitude (70 percent of total fall).

Evaluation of Results: If the components in the RC unit are normal, the waveform falls to approximately 30 percent of



(A) Test setup.

Fig. 28. Waveform at midpoint of the two-section symmetrical RC differentiating circuit.

(B) Waveform.

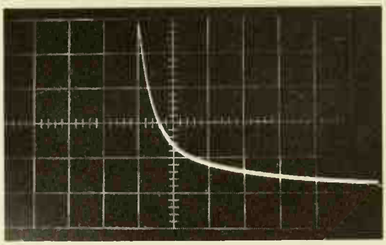


Fig. 28. Waveform at midpoint of the two-section symmetrical RC differentiating circuit. (cont'd.)

maximum in one time constant. The time constant is equal to the ohmic value of one of the resistors multiplied by the capacitance value of one of the capacitors, the product being in seconds.

U14

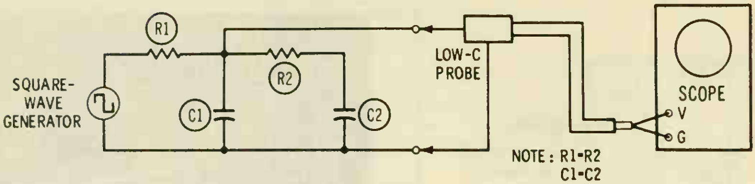
To Make a Midpoint Check of a Two-Section Symmetrical RC Integrator

Equipment: RC unit to be tested, square-wave generator, and scope with calibrated sweeps.

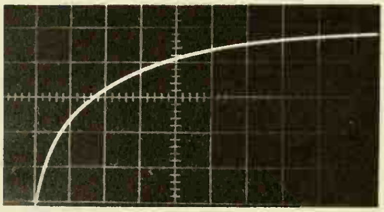
Connections Required: Connect the equipment as shown in Fig. 29A.

Procedure: Measure the elapsed time for the waveform to rise to 84 percent of maximum amplitude.

Evaluation of Results: If the capacitors and resistors in the unit are normal, the waveform will rise to approximately 84 percent of maximum in four time constants. The time constant in seconds is equal to the ohmic value of one of the resistors multiplied by the capacitance value of one of the capacitors, the answer being in seconds.



(A) Test setup.



(B) Waveform.

Fig. 29. Waveform at midpoint of the two-section symmetrical RC integrating circuit.

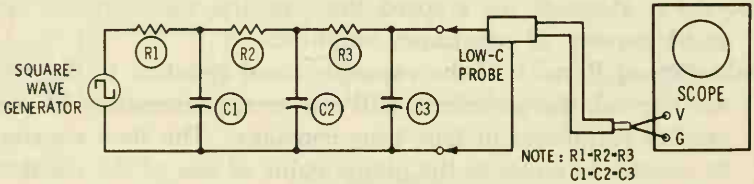
U15

To Check a Three-Section Symmetrical RC Integrating Circuit

Equipment: RC unit to be tested, square-wave generator, and scope with calibrated sweeps.

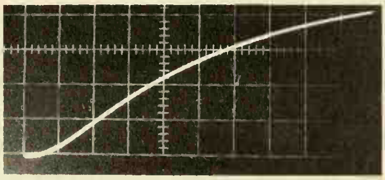
Connections Required: Connect the equipment as shown in Fig. 30A.

Procedure: Set the square-wave generator for a repetition rate that permits eight or nine time constants to be displayed. Measure the elapsed time to 63 percent of rise.



(A) Test setup.

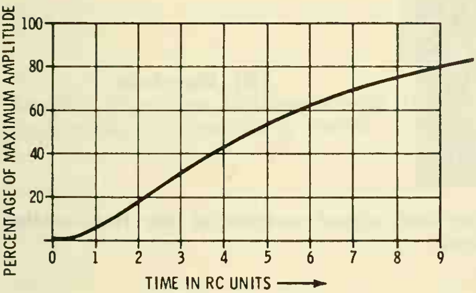
Fig. 30. Response of a three-section RC integrating circuit.



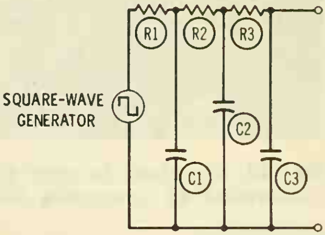
(B) Waveform.

Fig. 30. Response of a three-section RC integrating circuit (cont'd.)

Evaluation of Results: If the capacitors and resistors are normal in the integrator unit, the waveform will rise to 63 percent of maximum in approximately six time constants. The time constant is equal to the ohmic value of one of the resistors multiplied by the capacitance value of one of the capacitors in farads, the answer being in seconds. A universal RC time-constant chart for the three-section RC symmetrical integrator is shown in Fig. 31A.



(A) Chart.



(B) Circuit.

Fig. 31. RC time-constant chart for three-section integrator circuit.

U16

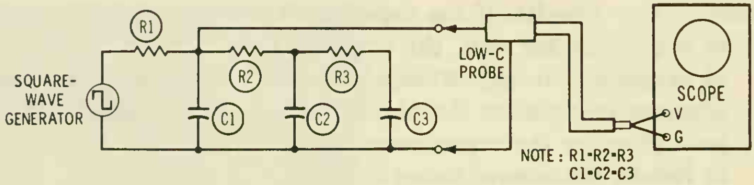
To Make a 1:2 Check of a Three-Section Symmetrical RC Integrator

Equipment: RC unit under test, square-wave generator, and scope with calibrated sweeps.

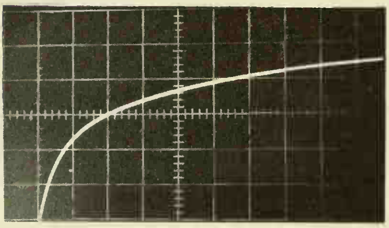
Connections Required: Connect the equipment as shown in Fig. 32A.

Procedure: Measure the elapsed time for the waveform to rise to 67 percent of its maximum amplitude.

Evaluation of Results: If the resistors and capacitors are normal, the waveform rises to 63 percent of its maximum amplitude in approximately four time constants.



(A) Test setup.



(B) Waveform.

Fig. 32. Waveform between first and second sections of the three-section symmetrical RC integrating circuit.

U17

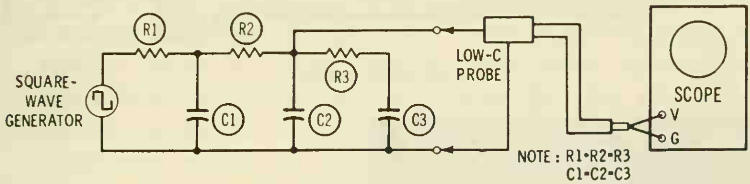
To Make a 2:3 Check of a Three-Section Symmetrical RC Integrator

Equipment: RC unit to be tested, square-wave generator, and scope with calibrated sweeps.

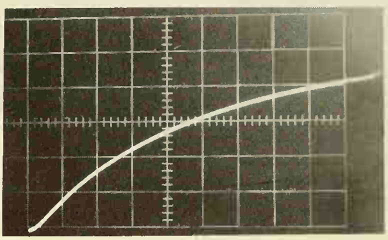
Connections Required: Connect the equipment as shown in Fig. 33A.

Procedure: Measure the elapsed time for the waveform to rise to 55 percent of its maximum amplitude.

Evaluation of Results: If the resistors and capacitors are normal, the waveform will rise to approximately 55 percent of its maximum amplitude in four time constants.



(A) Test setup.



(B) Waveform.

Fig. 33. Waveform between second and third sections of the three-section symmetrical RC integrating circuit.

U18

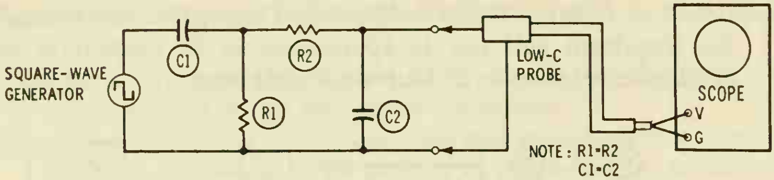
To Check a Two-Section Symmetrical RC Differentiating-Integrating Circuit

Equipment: RC unit to be tested, square-wave generator, and scope with calibrated sweeps.

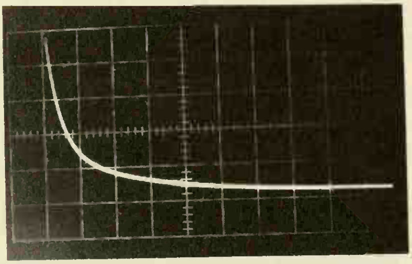
Connections Required: Connect the equipment as shown in Fig. 34A.

Procedure: Measure the elapsed time for the waveform to fall to 30 percent of its maximum amplitude (70 percent of fall).

Evaluation of Results: If the resistors and capacitors are normal, the waveform falls to approximately 30 percent of its maximum amplitude in four time constants.



(A) Test setup.



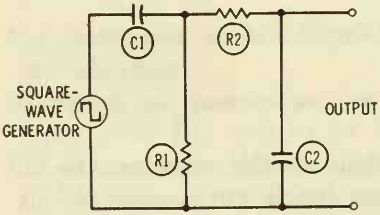
(B) Waveform.

Fig. 34. Waveform at the output of the symmetrical RC differentiating-integrating circuit.

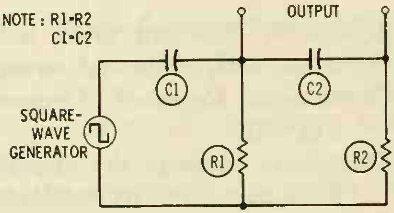
NOTE 9

Use of Single- and Double-Ended Scopes

The waveforms from the two circuits in Fig. 35 are the same because the output is taken from across the capacitor in the second section of both circuits. The waveform from the differentiator-integrator circuit can be checked with a single-ended scope. However, the waveform from the differentiator-differentiator circuit must be checked with a double-ended scope (scope with balanced input to the vertical amplifier). A double-ended scope is required because both terminals of the output are above ground in the differentiator-differentiator circuit.



(A) Differentiator-integrator circuit.



(B) Differentiator-differentiator circuit.

Fig. 35. The output waveforms from these two circuits are the same.

To Make an Equalized Time-Constant Check of an RC Circuit

Equipment: RC circuit to be tested, square-wave generator, scope with low-C probe, and a fixed capacitor of suitable value.

Connections Required: Connect the fixed capacitor across the resistor which is not shunted by capacitance; use a capacitance value which theoretically makes the time constants of the two circuit sections equal. Connect the square-wave generator and scope as shown in Fig. 36.

Procedure: Measure the rise time of the output waveform. Then, transfer the low-C probe to the output of the square-wave generator and measure the rise time of the input waveform.

Evaluation of Results: If the two rise times are equal (or very nearly equal), the network under test does not have a defective component. For example, the network comprising R1, R2, and C2 in Fig. 30 would be cleared from suspicion if the rise times of the input and output waveforms were the same.

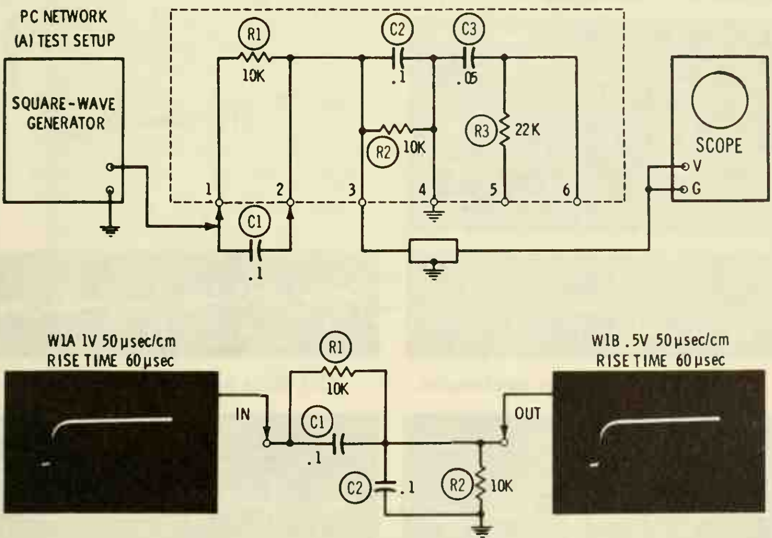


Fig. 36. Addition of C1 allows simple test; input and output waveshapes are identical.

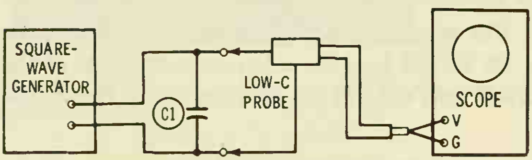
To Check a Capacitor for Residual Inductance

Equipment: Capacitor to be tested, square-wave or pulse generator with fast rise time (such as 0.02 microsecond), and scope with wide-band response.

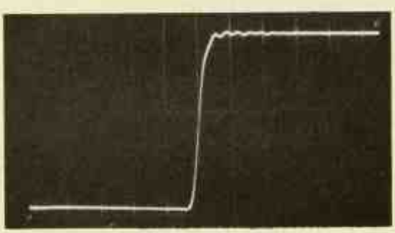
Connections Required: Connect the equipment as shown in Fig. 37A.

Procedure: Set the square-wave or pulse generator for a high repetition rate and operate the scope at comparatively high gain.

Evaluation of Results: The amount of ringing in the pattern indicates the amount of residual inductance in the capacitor. Large capacitors, in general, have more residual inductance than small capacitors. A small capacitor with good construc-

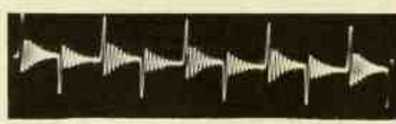


(A) Test setup.

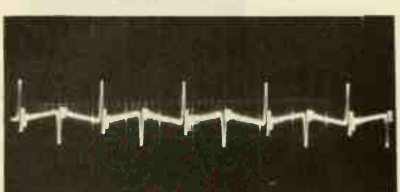


(B) Waveform.

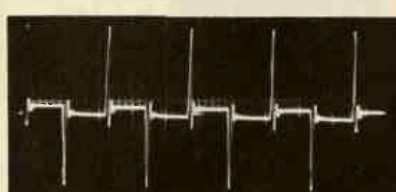
(C) Ringing across an electrolytic.



(D) Mica across the electrolytic.



(E) Ringing produced by a 0.5-mfd capacitor.



(F) Testing a low-voltage filter capacitor.

Fig. 37. Tests of capacitor for residual inductance.

tion will produce negligible ringing in the reproduced waveform. Note that the test leads must be kept very short in this test to avoid spurious ringing by the test leads acting as a tuned stub.

NOTE 10

Generator Output Impedance

When capacitance is shunted across the output terminals of a square-wave or pulse generator, the rise time of the waveform is slowed down, as shown for a typical generator in Fig. 38. The effect on rise time depends on the output impedance of the generator. Thus, a given value of capacitance slows down the rise more for a 600-ohm generator than for a 75-ohm generator. Hence, square-wave and pulse generators with low output impedances are more useful than generators with high output impedances.

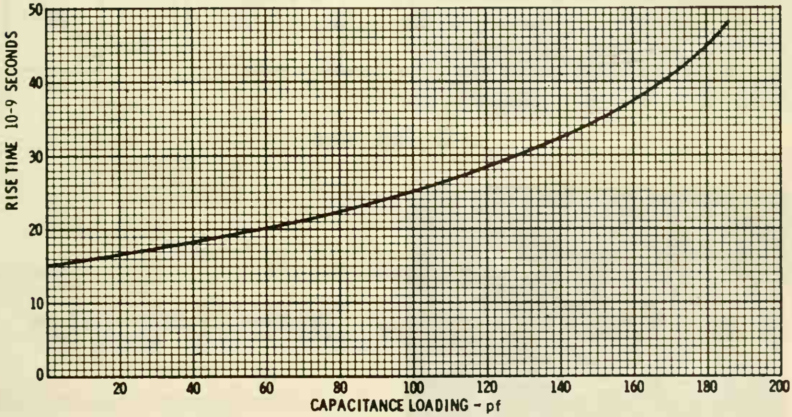


Fig. 38. A capacitance load slows down the rise time.

U21

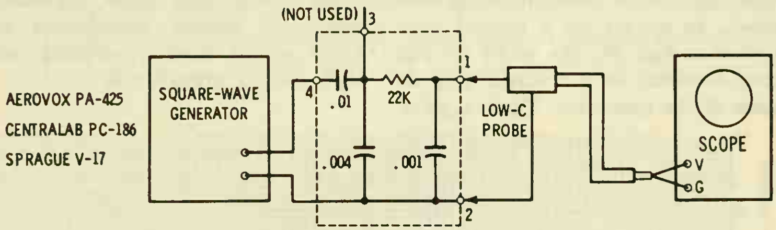
To Make a Square-Wave Test of a De-emphasis Network

Equipment: De-emphasis network to be tested, square-wave generator, and scope (preferably with triggered sweep and calibrated time base).

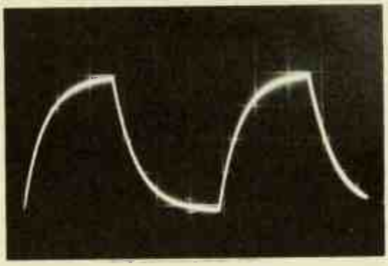
Connections Required: Connect the equipment as shown in Fig. 39A.

Procedure: Set the square-wave generator for a suitable repetition rate, such as 10 kc, and display the output waveform. The normal output waveform is illustrated in Fig. 39B.

Evaluation of Results: Defective capacitors or off-value resistors will cause a distorted output waveform. For an exacting test, the rise time of the output waveform should be measured. (See Fig. 40.) The waveform normally rises to 80 percent of maximum amplitude in 32 microseconds.



(A) Test setup.



(B) Normal output waveform.

Fig. 39. Test of a de-emphasis network.

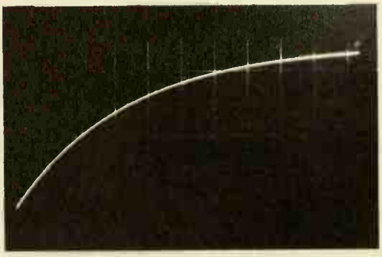


Fig. 40. Rise-time measurement. The waveform rises to 80 percent of the maximum amplitude in 32 microseconds.

NOTE 11

De-Emphasis Network

It is interesting to compare the square-wave response of a de-emphasis network with its sweep-frequency response. Fig. 41 illustrates the sweep-frequency response of the de-emphasis network shown in Fig. 39A. The frequency response is flat at low frequencies, and begins to fall at the higher audio frequencies. At 20 kc the response is down to approximately 25 percent of maximum amplitude.

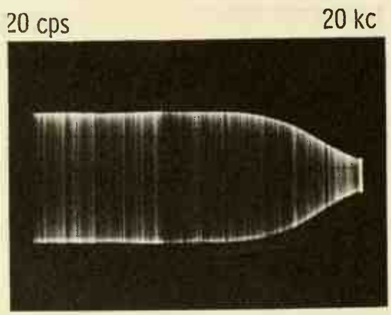


Fig. 41. Sweep-frequency response of a de-emphasis network.

U22

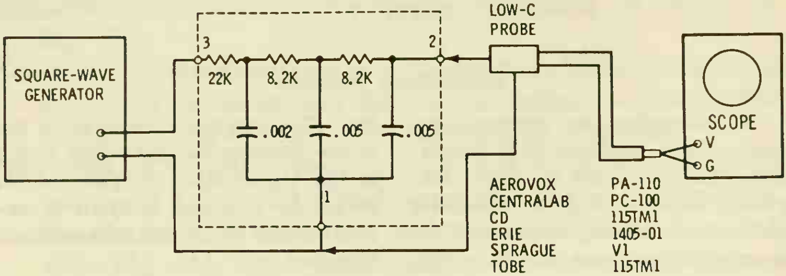
To Make a Square-Wave Test of a Vertical Integrator

Equipment: Integrator to be tested, square-wave generator, and scope (preferably with triggered sweeps and calibrated time base).

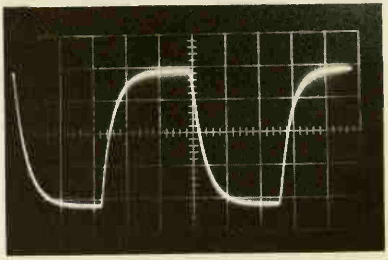
Connections Required: Connect the equipment as shown in Fig. 42A.

Procedure: Set the square-wave generator for a suitable repetition rate (such as 180 cps) and display the output waveform.

Evaluation of Results: The normal output waveform is illustrated in Fig. 42B. If there is a defective capacitor or off-value resistor in the network, the output waveform will be distorted. For an exacting test, the rise time of the output waveform should be measured. Fig. 43 shows the result of a rise-time measurement. The waveform normally rises to practically full amplitude in 1.6 milliseconds.



(A) Test setup.



(B) Normal output waveform.

Fig. 42. Test of a vertical integrator.

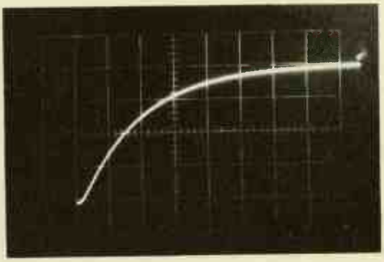


Fig. 43. The waveform rises to practically full amplitude in 1.6 milliseconds.

NOTE 12

Comparing Integrator Responses

It is interesting to compare the square-wave response of an integrator with its sweep-frequency response. Fig. 44 shows the normal sweep-frequency response for the integrator depicted in Fig. 42A. The sweep-frequency response is maximum at low frequencies, and tapers off at the higher audio frequencies. At 10kc the response falls to nearly zero.

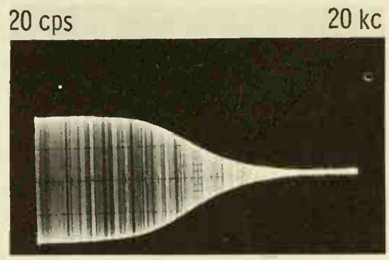


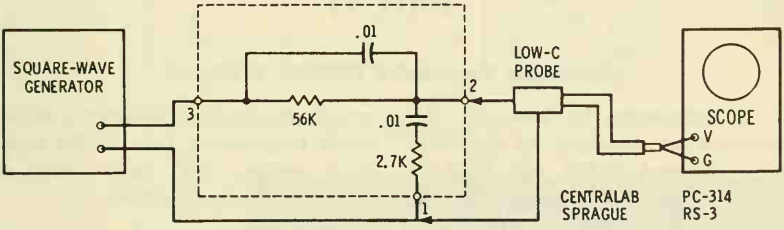
Fig. 44. Sweep-frequency response

U23

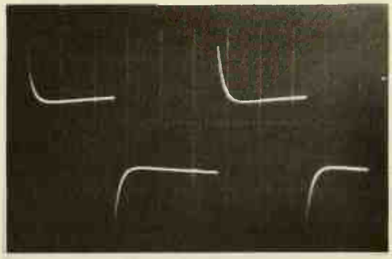
To Make a Square-Wave Test of a Retrace Suppression Network

Equipment: Retrace suppression network to be tested, square-wave generator, and scope (preferably with triggered sweeps and calibrated time base).

Connections Required: Connect the equipment as shown in Fig. 45A.



(A) Test setup.



(B) Normal square-wave response.

Fig. 45. Test of a retrace suppression network.

Procedure: Set the square-wave generator for a suitable repetition rate, such as 2500 cycles, and display the output waveform.

Evaluation of Results: The normal output waveform is illustrated in Fig. 45B. If there is a defective capacitor or off-value resistor in the network, the output waveform will be distorted. An exacting test can be made by measuring the fall time of the output waveform. Fig. 46 shows the normal-fall interval of the output waveform. In 25 microseconds, the waveform decays to approximately 10 percent of its maximum amplitude.

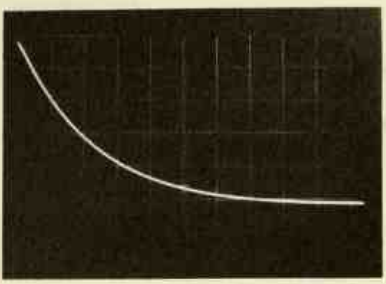


Fig. 46. Fall interval of the output waveform.

NOTE 13

Comparing Suppression Network Responses

It is interesting to compare the square-wave response of the network depicted in Fig. 45A with its sweep-frequency response. Fig. 47 illustrates the sweep response; the output amplitude is maximum at low audio frequencies, falls in the midband region, and rises again at higher audio frequencies.

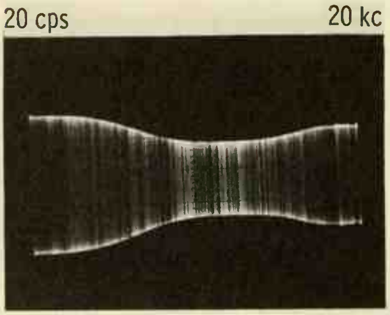


Fig. 47. Sweep-frequency waveform.

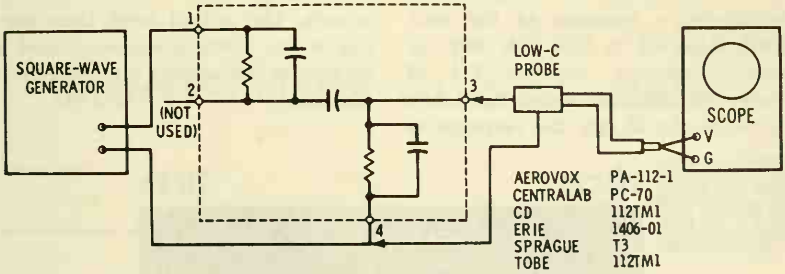
To Make a Square-Wave Test of a Triode-Coupling Network

Equipment: Coupling network to be tested, square-wave generator, and scope (preferably with triggered sweeps and calibrated time base).

Connections Required: Connect the equipment as shown in Fig. 48A.

Procedure: Set the square-wave generator to a suitable repetition rate, such as 60 cps, and display the output waveform.

Evaluation of Results: The normal output waveform is illustrated in Fig. 48B. If there is a defective capacitor or off-value resistor in the network, the output waveform will be distorted. A more exacting test can be made by measuring the fall time of the output waveform. Fig. 49 shows the fall interval. In 4 milliseconds, the waveform normally falls to approximately 25 percent of its maximum amplitude.



(A) Test setup.

(B) Square-wave response.

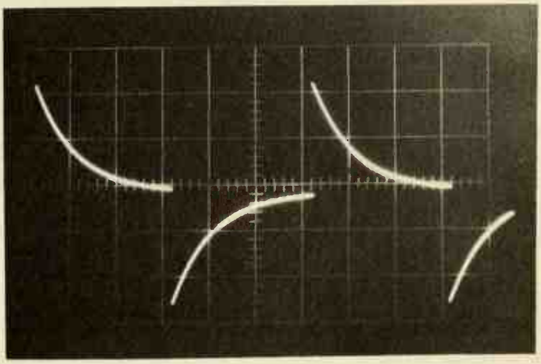


Fig. 48. Test of a triode-coupling network.

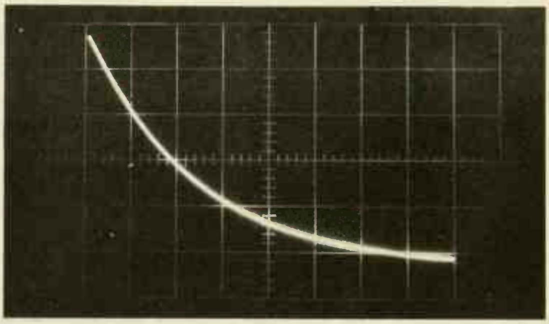


Fig. 49. Fall interval of output waveform.

NOTE 14

Comparing Triode-Coupling Network Responses

It is interesting to compare the square-wave response of the network depicted in Fig. 48A with its sweep-frequency response. Fig. 50 shows the normal sweep-frequency response. At 20 cps, the response is about 25 percent of maximum amplitude. The output level rises rapidly at low audio frequencies, and is maximum throughout the higher audio range.

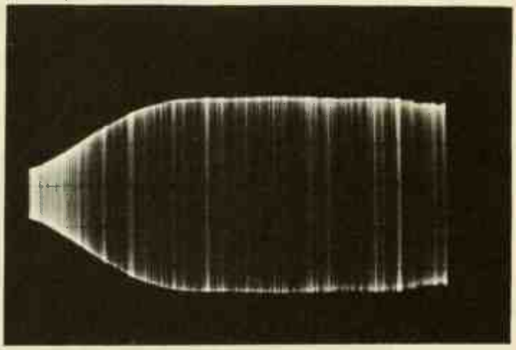


Fig. 50. Sweep-frequency response of network.

INDUCTIVE CIRCUITS AND COMPONENTS

U25

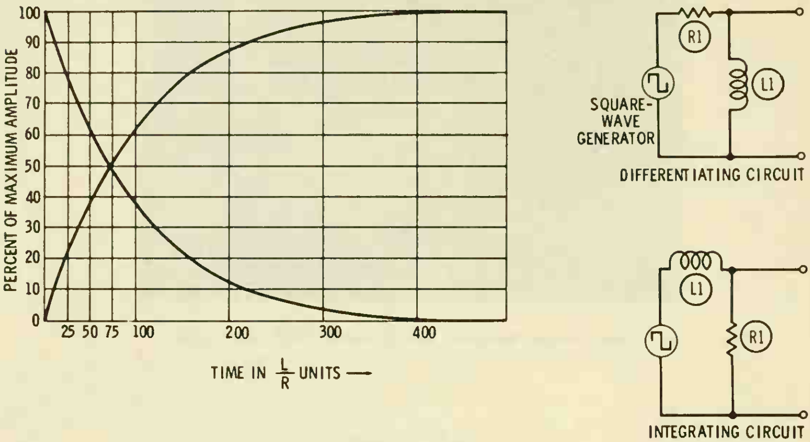
To Check an RL Differentiating or Integrating Circuit

Equipment: RL unit to be tested, square-wave generator, and scope with calibrated sweeps.

Connections Required: Connect the equipment as shown in Fig. 51B.

Procedure: Measure the time required for the waveform to rise to 63 percent of maximum amplitude, or to fall to 37 percent of maximum amplitude.

Evaluation of Results: If the inductor and resistor are normal, the output waveform rises to 63 percent of maximum amplitude, or falls to 37 percent of maximum amplitude in one time constant. The time constant of an RL differentiating or integrating circuit is equal to L/R seconds, where L is the inductance in henrys, and R is the resistance in ohms.



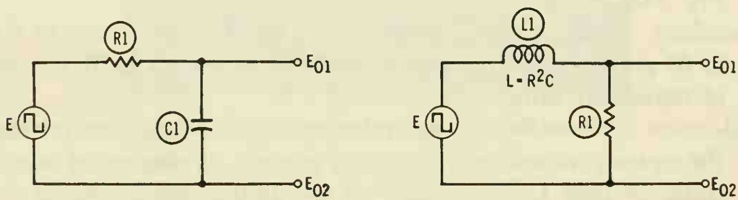
(A) Chart. (B) Circuits.

Fig. 51. A universal RL time-constant chart.

NOTE 15

RC and RL Circuits Can Be Equivalent

An RC circuit is equivalent to an RL circuit if the inductance in henrys is equal to R^2C, as shown in Fig. 52. In other words, these two circuits have the same time constant. This fact follows from the simple equation $RC = L/R$; solving for L, we obtain $L = R^2C$. Note that if the inductance has a large value, the output waveform may be different from the waveform predicted by simple theory, because a large inductance has appreciable distributed capacitance. In turn, the inductor does not respond practically as an ideal inductor; instead, the large inductor responds as a self-resonant circuit.



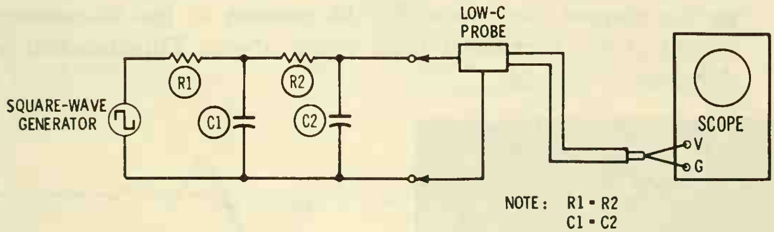
(A) A typical RC integrating circuit. (B) Equivalent RL integrating circuit with respect to E_{01} and E_{02}.

Fig. 52. An RC circuit can be equivalent to an RL circuit.

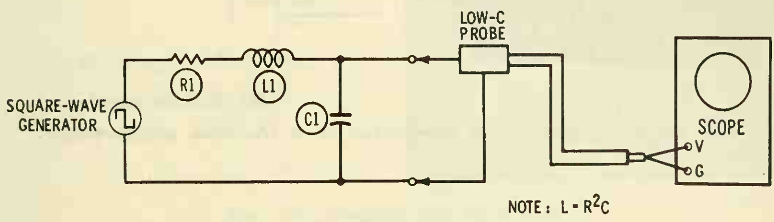
NOTE 16

Different Circuits Can Have the Same Response

An RLC series circuit with output taken from across capacitor C has the same square-wave response as a two-section symmetrical RC integrator when the R, L, and C values are related, as shown in Fig. 53. This is an example of the fact that circuits which appear to be quite different can nevertheless have the same square-wave response.



(A) Two-section symmetrical RC integrator.



(B) RLC circuit equivalent to a two-section symetrical RC integrator.

Fig. 53. Two circuits have the same output waveform.

U26

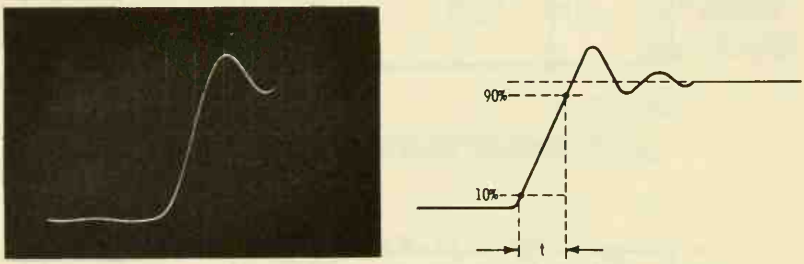
To Make a Measurement of Rise Time in the Presence of Overshoot

Equipment: Square-wave or pulse generator, circuit or device to be tested, and scope with calibrated time base.

Connections Required: Connect the equipment in the conventional manner to display the reproduced square wave or pulse.

Procedure: Note the horizontal level, as shown in Fig. 54, that corresponds to the flat top of the waveform, after the overshoot and ringing interval. In other words, overshoot is disregarded in determining the amplitude of the waveform.

Evaluation of Results: The rise time of the waveform is defined as the elapsed time from the 10 percent to the 90 percent points of the horizontal level noted above. This interval is depicted in Fig. 54.



(A) Scope trace. (B) Measurement.

Fig. 54. Overshoot is not considered in a rise-time measurement.

U27

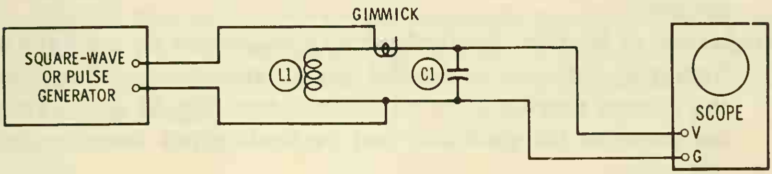
To Make a Ringing Test of a Coil

Equipment: Coil to be tested, square-wave or pulse generator with fast rise, and scope with sufficient vertical bandwidth to display the ringing frequency.

Connections Required: Connect the equipment as shown in Fig. 55A. (Capacitor C may be omitted.)

Procedure: Adjust the square-wave or pulse generator for a repetition rate sufficiently low so that the ringing pattern is permitted to decay to a fraction of its initial amplitude. The time base of the scope is adjusted to match the repetition rate of the generator.

Evaluation of Results: The Q of the coil is equal to π (3.14) multiplied by the number of cycles (peaks) in the ringing waveform from its maximum point to its 37 percent-of-maximum point, as shown in Fig. 56. This is the Q value at the natural resonant frequency of the coil. To measure the Q value at lower frequencies, shunt a fixed or variable capacitor across the coil.



(A) Test setup.

(B) Ringing waveform.

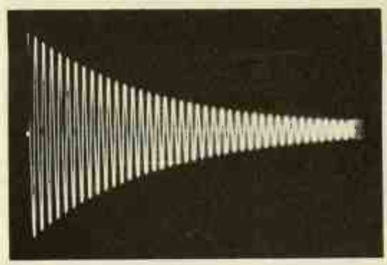


Fig. 55. Ringing test of a coil.

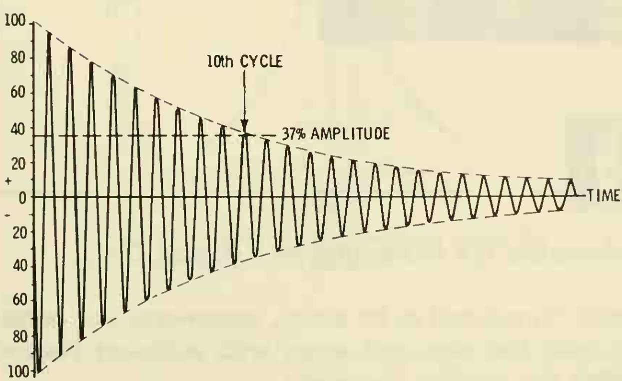


Fig. 56. Q equals 10π, equals 31.4 in this example.

To Make a Ringing Test of a Vertical-Sweep Component

Equipment: Same as for making a ringing test of a single coil.

Connections Required: Connect the largest winding of the component (primary of an output transformer, or secondary of a blocking-oscillator transformer) to the vertical-input terminals of the scope.

Procedure: A horizontal deflection rate of about 800 cycles is suitable.

Evaluation of Results: Vertical-sweep components do not have as high a Q value as horizontal-sweep components. Therefore, the normal ringing patterns decay faster. Fig. 57 shows ringing patterns for good and bad vertical-output transformers.

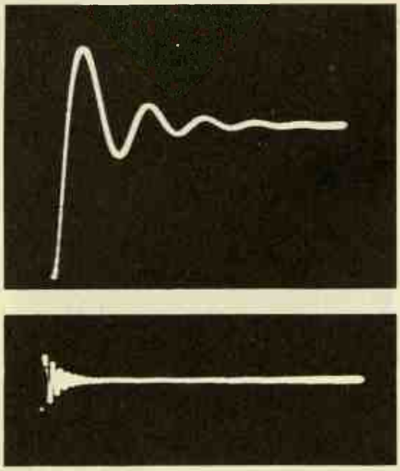


Fig. 57. Good and bad vertical-output transformer waveforms.

U29

To Measure the Bandwidth of a Tuned Coil

Equipment: Tuned coil to be tested, square-wave or pulse generator with fast rise, and scope with sufficient bandwidth to display the ringing frequency.

Connections Required: Connect the equipment as shown in Fig. 58.

Procedure: Tune the coil to the desired frequency (may be checked by means of a grid-dip meter or, if you are using a scope with calibrated sweeps, the ringing frequency may be read from the time-base controls). Measure the Q value as previously explained.

Evaluation of Results: The bandwidth of a tuned coil is defined as the difference between the frequencies at which the response is down 3 db, or 0.707 of maximum, as depicted in Fig. 59. The bandwidth is approximately equal to f_r/Q, where f_r is the ringing frequency. Fig. 60A shows the response curve for a tuned circuit with a 100-mh coil, 25.3-pf capacitor, and 12-ohm resistor.

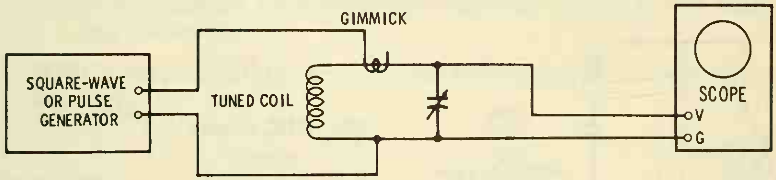


Fig. 58. Test setup for measuring the bandwidth of a tuned coil.

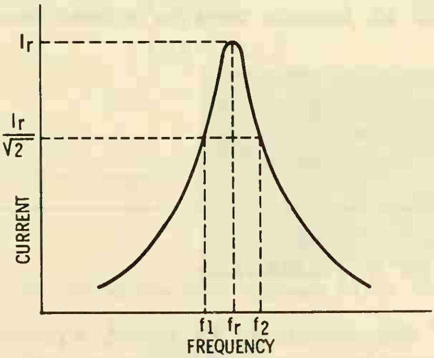
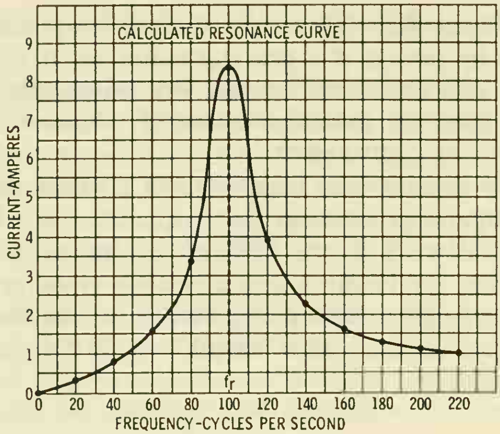
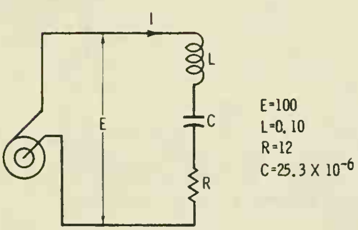


Fig. 59. Bandwidth is the frequency range between the half-power points.



(A) Frequency response of an RLC circuit.



(B) RLC circuit.

Fig. 60. Response curve for a tuned circuit.

U30

To Check an IF Transformer

Equipment: IF transformer to be tested, square-wave or pulse generator with fast rise time, and scope with sufficient bandwidth to display the ringing frequency.

Connections Required: Connect the equipment as shown in Fig. 61A.

Procedure: Adjust trimmers on the transformer to resonate both the primary and secondary windings at the rated operating frequency. The ringing frequency can be read from the time-base control settings, if you are using a triggered-sweep scope.

Note that the primary and secondary windings are tuned to the same frequency when the ringing waveform has maximum amplitude. Measure the elapsed time from the peak of one ringing sequence to the peak of the next ringing sequence.

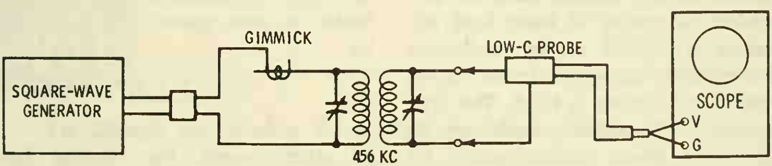
Evaluation of Results: The ringing pattern can be used as a comparison test for various transformers. The elapsed time from one maximum peak to the next minimum peak also gives the separation of the two humps in cycles (see Fig. 62). Thus, the number of cycles from A to A′ in Fig. 62B is given by:

$$f_2 - f_1 = \frac{1}{2T}$$

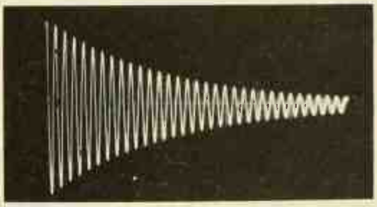
where,

f_2 is the frequency at one hump,
f_1 is the frequency at the other hump, and
T is the elapsed time between maximum peaks in the ringing waveform.

With looser coupling, the humps will occur at B and B′ in Fig. 62B.



(A) Setup.



(B) Ringing-pattern waveform.

Fig. 61. Displaying the square-wave response of an IF transformer.

NOTE 17

Transformer Ringing Test

The basic principle of the transformer ringing test is as follows: A tuned transformer has two tuned coils, and in turn the primary is loaded by the secondary and vice versa, because of the coupling between the coils. This loading results in two ringing frequencies, even when the coils are tuned to the same center frequency. Because two different ringing frequencies are present, a beat pattern is reproduced

on the scope screen. Coupling produces a reflection of electrical energy back and forth between the primary and secondary. In other words, the ringing energy rises to a maximum in the primary, and then starts to decay. But as the primary energy starts to decay, it is coupled into the secondary, causing a ringing waveform to build up in the secondary. Next, the secondary energy starts to decay, and the decaying energy is coupled back into the primary. Successive peaks have reduced amplitude because there is an I^2R loss in the resistances of the primary and secondary windings. When the primary and secondary are tuned to exactly the same frequency, the ringing waveform goes completely to zero at the end of each successive ringing interval. The number of cycles in each beat sequence is related to the coefficient of coupling—there are fewer cycles when the coupling is tight. The frequency of the ringing waveform in Fig. 61 is given approximately by the standard resonant-frequency formula:

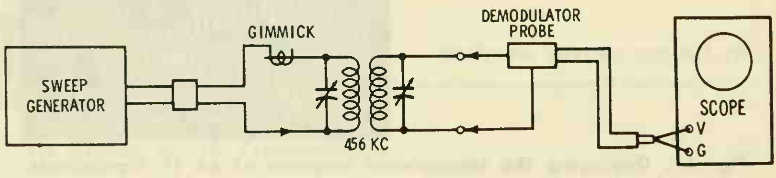
$$f = \frac{1}{2\pi\sqrt{LC}}$$

where,
- L is the inductance of the primary (or of the secondary), and
- C is the capacitance shunted across the primary (or secondary).

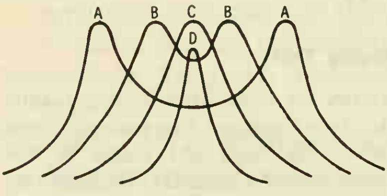
We are assuming here that the primary and secondary inductances are the same, and that the primary and secondary capacitances are the same, which is true of nearly all tuned-IF transformers. With respect to Fig. 62B, consider the hump frequencies A, A'. Let us denote these hump frequencies by f_1 and f_2, because the right-hand hump has a higher frequency than the left-hand hump. Then, the ringing frequency, which was given approximately by the standard resonant-frequency formula, is also given approximately by:

$$f_r = \frac{f_1 + f_2}{2}$$

In other words, the ringing frequency f_r is the average of the two hump frequencies.



(A) Setup.



(B) Response curves for different coefficients of coupling.

Fig. 62. Displaying the frequency response of an IF transformer.

AUDIO-AMPLIFIER TESTS

U31

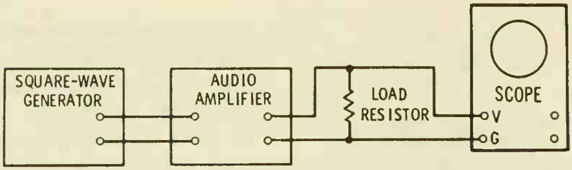
To Check an Audio Amplifier for Square-Wave Response

Equipment: Amplifier to be tested, load resistor of rated value, square-wave generator, and scope with better response than the audio amplifier.

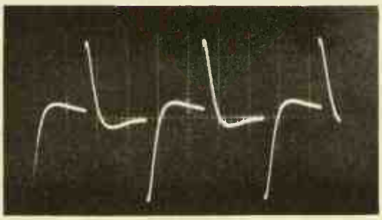
Connections Required: Connect the equipment as shown in Fig. 63A.

Procedure: Set the square-wave generator to 60-cycle repetition rate and observe the scope pattern. Then, advance the repetition rate to 2 kc and observe the scope pattern.

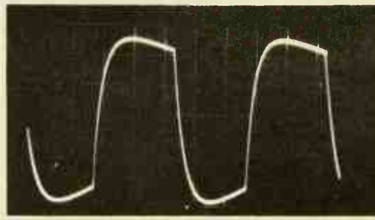
Evaluation of Results: A distortionless audio amplifier would reproduce undistorted square waves at both 60 cycles and 2 kc. However, we expect to observe more or less distortion. The illustrations in Figs. 63B and C show a large amount of distortion, which is typical of economy-type audio amplifiers. When a utility-type amplifier is under test, it is standard practice to check the square-wave response at a 60-cycle and at a 2-kc repetition rate. Of course, other repetition rates can also be used, if desired.



(A) Test setup.



(B) Poor 60-cycle square-wave response.



(C) Poor 2-kc square-wave response.

Fig. 63. Square-wave test of an audio amplifier.

U32

To Check a Single Stage in an Audio Amplifier

Equipment: Amplifier to be tested, square-wave generator, and scope with low-capacitance probe. The scope should have a better response than the stage under test.

Connections Required: Connect the equipment as shown in Fig. 64.

Procedure: Set the square-wave generator for a repetition rate of 60 cps and observe the waveform on the scope screen. Then, set the square-wave generator for a repetition rate of 2 kc and observe the waveform on the scope screen.

Evaluation of Results: Each stage in the amplifier may be checked for square-wave response in this manner. Observe the comparative stage responses. If one of the stages has excessive distortion, check the associated capacitors for leakage or opens, and check for off-value resistors.

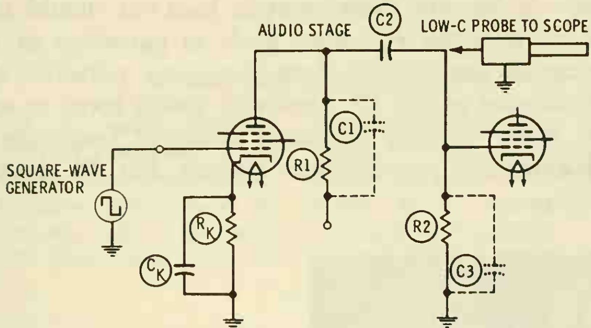


Fig. 64. Square-wave response is determined by values of R1, C1, C2, R2, and C3.

NOTE 18

Stray Capacitance Limits High-Frequency Response

The high-frequency response of an audio stage is limited by the stray capacitance C1 (Fig. 64) shunting the plate-load resistor, plus the stray capacitance C3 shunting the grid resistor. A lower value for plate-load resistor R1 will produce better high-frequency response. Low-frequency response is limited by the values of coupling capacitor C2 and bypass capacitor C_k. If these values are increased, the low-frequency response will be improved.

U33

To Check the Action of Tone Controls in an Audio Amplifier

Equipment: Amplifier to be tested, square-wave generator, load resistor of rated value, and scope with better response than the audio amplifier.

Connections Required: Connect the equipment as previously explained for square-wave test of an audio amplifier.

Procedure: Set the square-wave generator for a 60-cps repetition rate; observe the scope pattern as the bass and treble controls are turned through their ranges. Next, set the generator for a 2-kc repetition rate; observe the scope pattern as the bass and treble controls are turned through their ranges.

Evaluation of Results: Bass boost or bass cut should take place without spurious responses such as parasitics or excessive ringing at any setting. Low-frequency parasitic oscillation is illustrated in Fig. 65. Similarly, treble boost or cut should take place without excessive spurious responses such as high-amplitude or sustained ringing. Fig. 66 shows typical patterns.

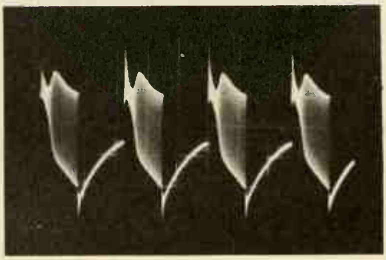
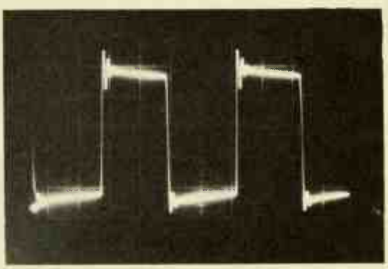
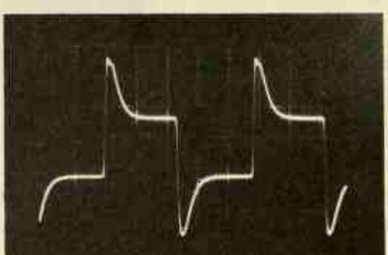


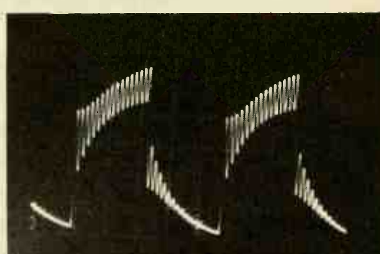
Fig. 65. Parasitic oscillation in the 60-cycle square-wave pattern.



(A) 2-kc square-wave response in "crisp" position.



(B) 2-kc square-wave response in "brilliant" position.



(C) 2-kc square-wave response in "deep bass" position.

Fig. 66. Typical treble boost or cut patterns.

NOTE 19

Overload Should Be Avoided

Overload of an audio amplifier should be avoided in any test. When overload occurs, the top and bottom of the reproduced square wave do not have the same shape, as shown in Fig. 67. In other words, overload causes false flat-topping. Reduce the output from the square-wave generator to the point where the top and bottom of the square wave have symmetrical excursions.

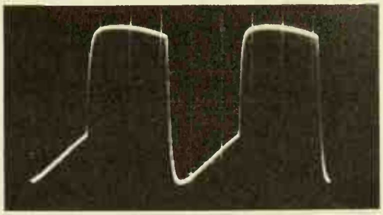


Fig. 67. Overdriven amplifier produces false flat-topping.

U34

To Check the Operation of a Negative-Feedback Loop in an Audio Amplifier

Equipment: Amplifier to be tested, square-wave generator, load resistor of rated value, and scope with better response than the audio amplifier.

Connections Required: Connect the equipment as shown in Fig. 68.

Procedure: Observe the square-wave response of the amplifier at a 2-kc repetition rate. Then, open the feedback loop. Fig. 69 shows the schematic of a typical amplifier with negative feedback from the secondary of the output transformer. The pattern normally increases greatly in height when the feedback loop is opened. Reduce the output from the square-wave generator to avoid overloading the amplifier.

Evaluation of Results: If the height of the pattern and the shape of the reproduced square wave are unaffected or are only slightly affected by opening the feedback loop, there is a defect in the feedback circuit. Look for a resistor that might have increased in value, or an open ground connection.

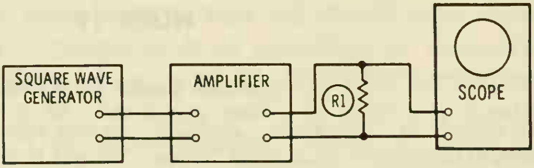
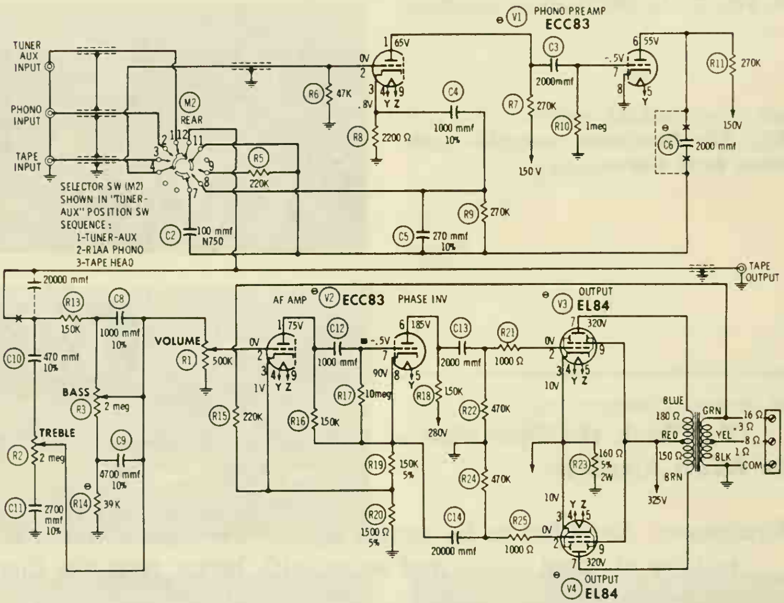
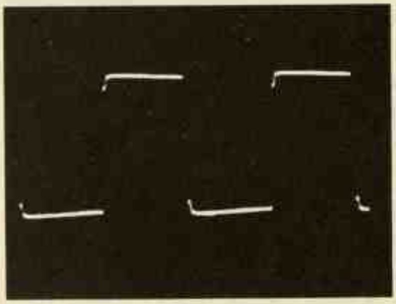


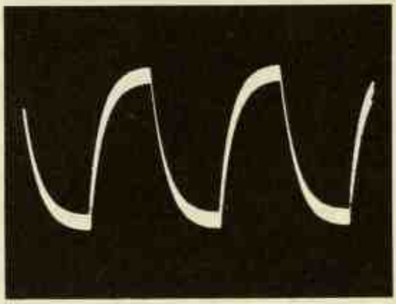
Fig. 68. Test setup for negative-feedback loop.



(A) Schematic of simple high-fi amplifier with negative feedback.



(B) Normal 2-kc square-wave response.



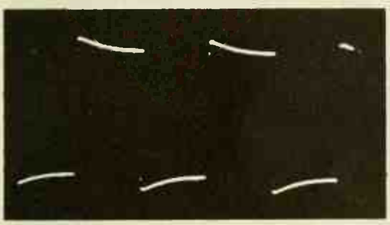
(C) Response at 2 kc with feedback loop defective.

Fig. 69. Effect of negative-feedback loop output on square-wave response.

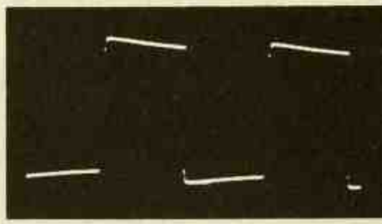
NOTE 20

Make Comparison Check Above 2 Kc

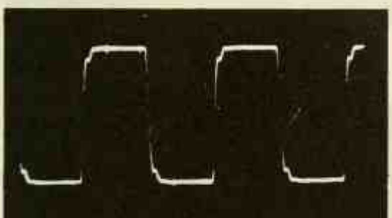
Since a hi-fi amplifier has extended high-frequency response compared to a utility audio amplifier, it is advantageous to check the square-wave response at repetition rates higher than 2 kc. Fig. 70 shows normal square-wave responses of a simple hi-fi amplifier. If the manufacturer publishes rated square-wave responses for the amplifier, a comparison check is very helpful. The effect of tone-control settings on square-wave response of the hi-fi amplifier is seen in Fig. 71.



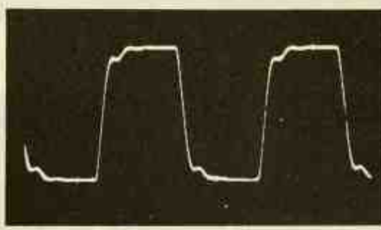
(A) 500 cycles.



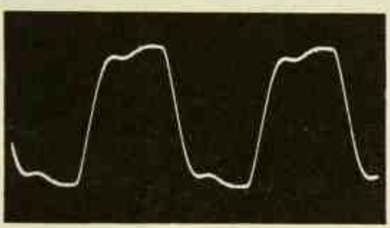
(B) 1 kc.



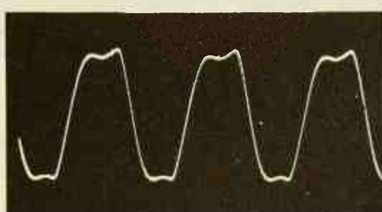
(C) 5 kc.



(D) 10 kc.



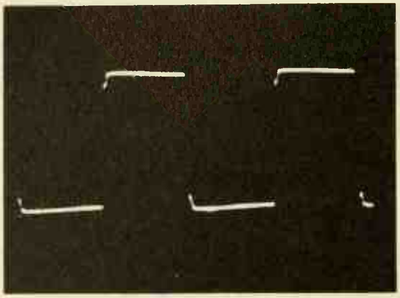
(E) 20 kc.



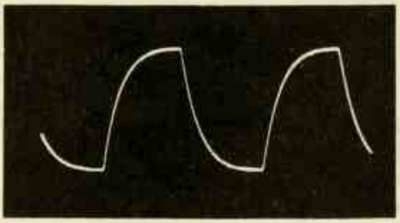
(F) 30 kc.

(G) 50 kc.

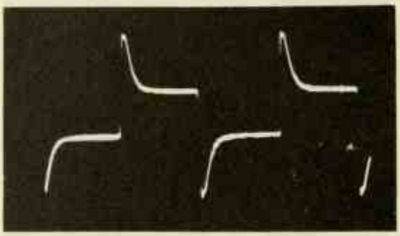
Fig. 70. Normal square-wave response of a simple hi-fi amplifier.



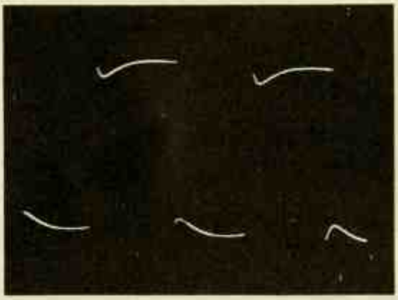
(A) 2 kc, base and treble controls at midrange.



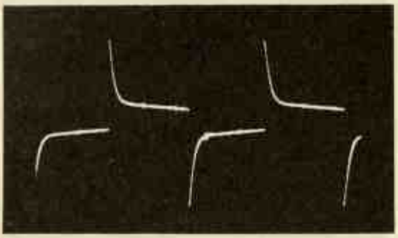
(B) 2 kc, treble control at full left.



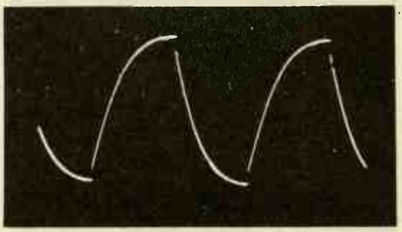
(C) 2 kc, treble control at full right.



(D) 60 cycles, bass and treble control.



(E) 60 cycles, bass and treble control at midrange.



(F) 60 cycles, bass control at full right.

Fig. 71. Effect of tone-control settings on square-wave response.

U35

To Measure the Rise Time and High-Frequency Cutoff Point of an Audio Amplifier

Equipment: Audio amplifier to be tested, load resistor of proper value, square-wave generator, and scope with better response than the amplifier under test.

Connections Required: Connect the equipment as previously explained for square-wave test.

Procedure: Set the square-wave generator to an appropriate repetition rate, such as 2 kc for a utility amplifier, or 30 kc for a hi-fi amplifier. Expand the leading edge of the displayed square wave, as shown in Fig. 72. Measure the rise time from 10 percent to 90 percent of full amplitude.

Evaluation of Results: The rise time may be checked against the manufacturer's rating on the amplifier. If the rise is too slow, there may be a defect in the negative-feedback circuit. Another cause of slow rise is an increase in value of one or more of the plate-load resistors. The high-frequency cutoff point of the amplifier is given by:

$$f_c = 0.35/T$$

where,

f_c is the point at which the frequency response is 3 db down,
T is the rise time of the amplifier.

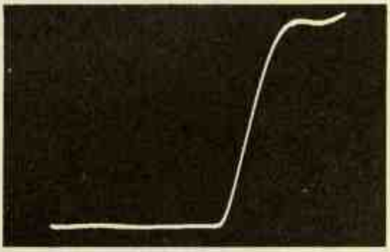


Fig. 72. Leading edge of 30-kc response pattern.

U36

To Measure the Tilt and Low-Frequency Cutoff Point of an Audio Amplifier

Equipment: Audio amplifier to be tested, load resistor of rated value, square-wave generator, and scope with better low-frequency response than the audio amplifier.

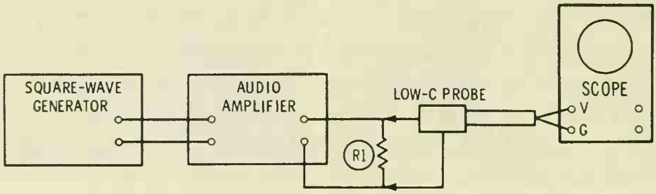
Connections Required: Connect the equipment as shown in Fig. 73A.

Procedure: Reduce the repetition rate of the square-wave generator until the waveform has from 10 percent to 15 percent tilt, as depicted in Fig. 73B.

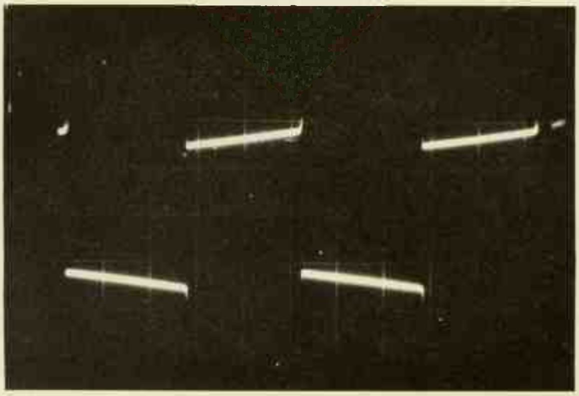
Evaluation of Results: The percentage of tilt is given by:

$$\frac{E_2 - E_1}{E_2} \times 100$$

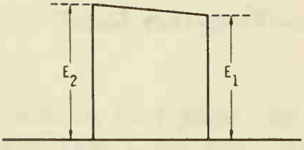
The low-frequency cutoff point of the audio amplifier, where the response is 3 db down, is given approximately by the formula:



(A) Setup.



(B) Waveform.



(C) Measurement of tilt.

Fig. 73. Audio amplifier displays tilt at low repetition rates.

$$f_c = \frac{2f\,(E_2 - E_1)}{3\,(E_2 + E_1)}$$

where,

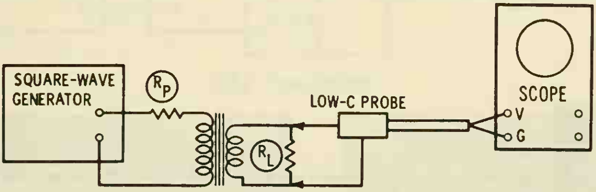
f_c is the cutoff frequency,
f is the square-wave frequency,
E_2 and E_1 are the amplitudes shown in Fig. 73C.

U37

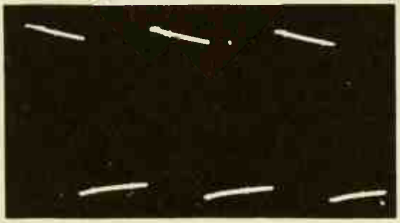
To Check the Square-Wave Response of an Audio Transformer

Equipment: Audio transformer to be tested, primary and secondary load resistors of suitable values, square-wave generator, and scope.

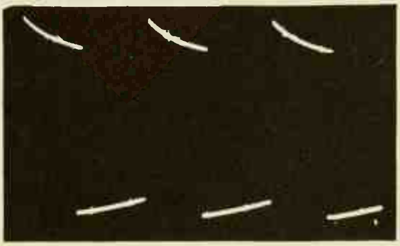
Connections Required: Connect the equipment as shown in Fig. 74A. Resistor R_p has a value equal to the plate resistance of the tube with which the transformer is intended to operate, and R_L has a value equal to the voice-coil impedance



(A) Test setup.



(B) Waveform with low-level signal.



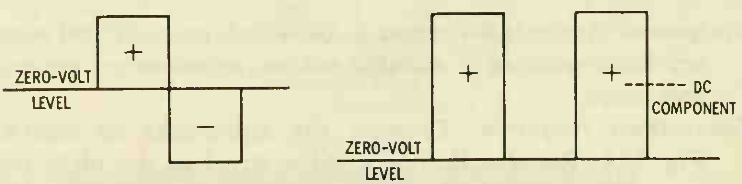
(C) Core driven into saturation.

Fig. 74. High-level square wave is unsymmetrical.

of the speaker with which the transformer is intended to operate.

Procedure: Observe the reproduced square-wave pattern at the 60-cps and 2-kc repetition rates. Keep the square-wave signal level below the point at which the waveform becomes noticeably unsymmetrical.

Evaluation of Results: A hi-fi transformer normally provides good square-wave response at 60 cps and at 2 kc. On the other hand, an economy-type transformer tends to develop serious tilt at 60 cps, and may ring objectionably at 2 kc. Small transformers may be overloaded and display an unsymmetrical output waveform unless the level of the square-wave signal is suitably limited. Overload shows up most prominently when the square-wave generator has a DC output (see Fig. 75).



(A) With AC-coupled output. (B) With DC-coupled output.

Fig. 75. A square-wave generator may or may not have a DC component in its square-wave output.

U38

To Make a Pulse-Response Test of an Audio Amplifier

Equipment: Audio amplifier to be tested, load resistor of suitable value, pulse generator, and oscilloscope (preferably with triggered sweep and calibrated time base).

Connections Required: Connect the equipment as shown in Fig. 76A.

Procedure: Reduce the pulse width until the output waveform is integrated from zero to the 100-percent point, as illustrated in Fig. 76B. Measure the rise time of the reproduced pulse.

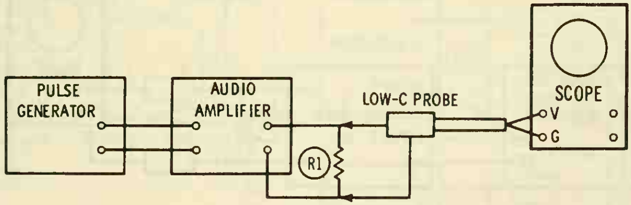
Evaluation of Results: A comparative test of hi-fi amplifiers can be made by observing the reproductions of pulses with a width of about 100 microseconds. The best amplifier will pass the narrow pulse with less integration and with less ringing (waviness) along the contour of the integrated waveform. The high-frequency cutoff point of the audio amplifier is given by:

$$f_c = 0.35/T$$

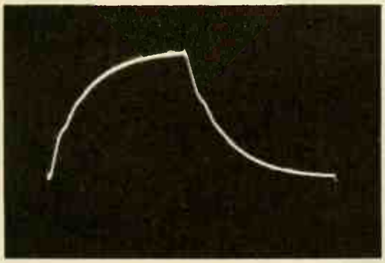
where,

f_c is the frequency at which the response is 3 db down, and
T is the rise time of the reproduced pulse waveform.

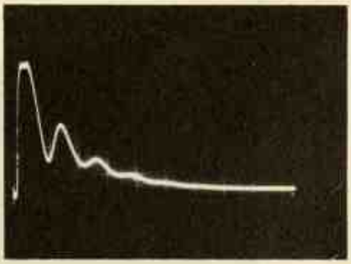
Note that it is pointless to make this test with an excessively narrow pulse; when the test pulse is too narrow, the input-signal level must be abnormally increased and the gain of the audio amplifier must be unduly advanced to obtain a pattern on the scope screen. In such a case, we observe chiefly a feedthrough voltage (Fig. 76C) which does not show the normal response of the amplifier.



(A) Test setup.



(B) 100-μs pulse width.



(C) 1-μs pulse width.

Fig. 76. Response of audio amplifier to narrow pulses.

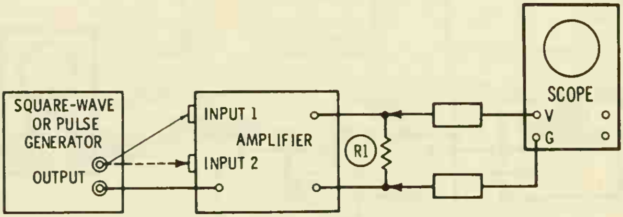
To Check an Audio Amplifier for Cross Talk Between Inputs

Equipment: Square-wave or pulse generator, amplifier to be tested, load resistor of suitable value, and oscilloscope.

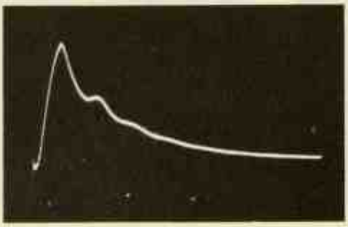
Connections Required: Connect the equipment as shown in Fig. 77A.

Procedure: Adjust the output level of the generator for rated maximum power output from the amplifier, as measured by a calibrated scope with the generator connected to input 1 and the amplifier switched to input 1. Then, switch the amplifier to input 2 and observe the output-waveform amplitude (if any). Next, repeat the test with the generator connected to input 2 and the amplifier switched to input 1.

Evaluation of Results: The value of cross talk is given by the number of db difference between waveform amplitudes when the amplifier is switched from one input to the other. Note that some audio amplifiers are designed to operate with one input shorted while the other is in use, to minimize cross talk.



(A) Test setup.



(B) Waveform.

Fig. 77. Checking for cross talk between inputs.

To Check for Cross Talk Between Stereophonic Amplifiers

Equipment: Square-wave or pulse generator, stereo amplifier to be tested, two load resistors of suitable values, and oscilloscope.

Connections Required: Connect the equipment as shown in Fig. 78.

Procedure: Adjust the output level of the generator for maximum rated power output from the amplifier, as measured by a calibrated scope, with the scope connected across the output of the channel to which the amplifier is set. Then, switch the amplifier to the other channel and observe the output-waveform amplitude (if any). Next, repeat the test with the scope connected across the output of the other channel.

Evaluation of Results: The cross-talk value is the number of db difference between waveform amplitudes when the amplifier is switched from one channel to the other. To minimize cross talk, adjust the balance control of the amplifier as required.

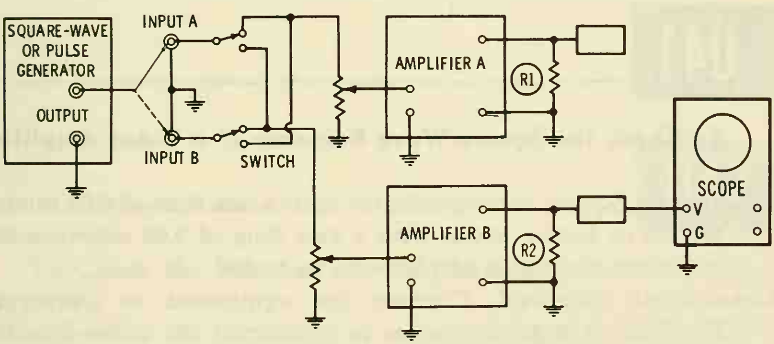


Fig. 78. Cross-talk check of a stereo amplifier.

TELEVISION-RECEIVER TESTS

U41

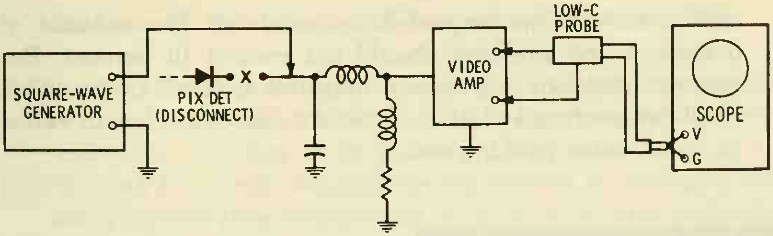
To Check the Square-Wave Response of a Video Amplifier

Equipment: Square-wave generator with a rise time of 0.08 microsecond or better, scope with a rise time of 0.08 microsecond or better, and video amplifier to be tested.

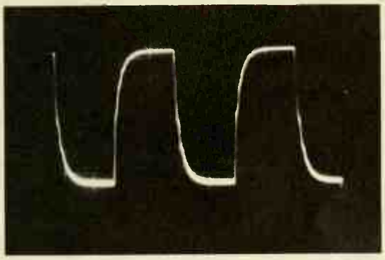
Connections Required: Connect the equipment as shown in Fig. 79A. It is good practice to disconnect the video-detector diode to avoid possible waveform distortion.

Procedure: Check the square-wave response of the video amplifier at a square-wave repetition rate of 100 kc. Higher and lower repetition rates can also be used, if desired.

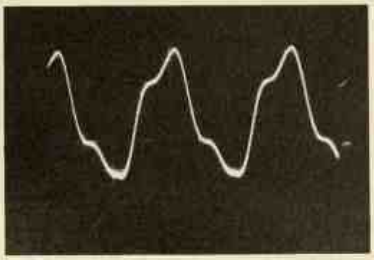
Evaluation of Results: A 100-kc square wave will usually show more or less integration, unless the video amplifier has been designed for high performance. The 100-kc waveform photo illustrated in Fig. 79B is typical of economy-type TV receivers. Excessive integration points to a defect in the video amplifier, such as a plate-load resistor which has increased in value, or a shorted peaking coil.



(A) Test setup.



(B) 100-kc waveform.



(C) 1-mc waveform.

Fig. 79. Checking the square-wave response of a video amplifier.

U42

To Check the Response of the Video Amplifier in a Color Receiver

Equipment: Same as in U41.

Connections Required: Same as in U41.

Procedure: The basic check of video-amplifier response (sometimes called the Y-amplifier response) is made at a square-wave repetition rate of 100 kc. Higher or lower repetition rates can also be used, if desired.

Evaluation of Results: In general, the video amplifier in a color-TV receiver has better square-wave response than in a black-and-white receiver. An illustration of normal 100-kc square-wave response is shown in Fig. 80. Observe that the reproduced square wave is not integrated. Instead, there is notice-

able overshoot, accompanied by preshoot. The amount of overshoot and preshoot should not exceed 10 percent. Excessive overshoot or preshoot indicates a defect in the video amplifier, such as a plate-load resistor that is too low in value, or an off-value peaking coil.

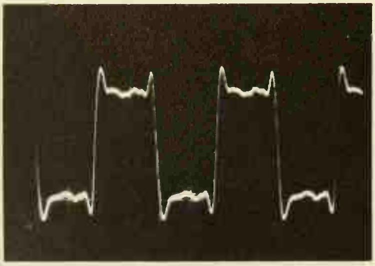


Fig. 80. Example of preshoot and overshoot in the 100-kc square-wave response of a color-TV video amplifier.

NOTE 21

Video-Amplifier Overshoot Indicates Peaked Response

Overshoot in a video-amplifier square-wave test indicates that the frequency response of the amplifier is not flat, but is peaked. An example is depicted in Fig. 81. The amplifier tends to overshoot and ring at the peak resonant frequency. A small amount of overshoot is usually considered desirable, because it makes the picture appear "crisper." Preshoot that matches the overshoot is obtained only in video amplifiers that have phase compensation. Color-TV video amplifiers commonly provide phase compensation in their circuitry.

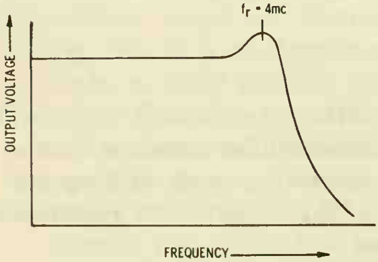


Fig. 81. A peaked video-amplifier frequency response causes square-wave overshoot.

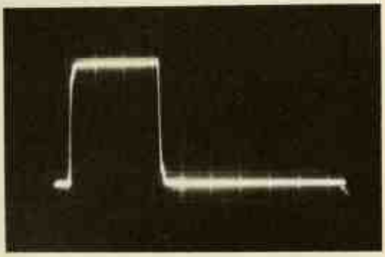
To Make a Pulse-Response Test of a Video Amplifier

Equipment: Pulse generator with rise time of 0.08 microsecond or better, scope with rise time of 0.08 microsecond or better, and video amplifier to be tested.

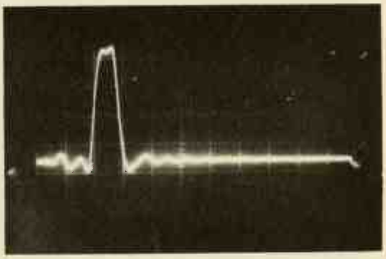
Connections Required: Connect the equipment as shown in U41, using a pulse generator instead of the square-wave generator.

Procedure: Observe the reproduced pulse waveform at 100-microsecond and a 1-microsecond pulse width. Other pulse widths can also be used, if desired.

Evaluation of Results: A 100-microsecond pulse is normally displayed with only minor distortion, as seen in Fig. 82A. However, a 1-microsecond pulse imposes a severe test on the video amplifier; its amplitude will be quite a bit less than in the display of the 100-microsecond pulse, and the scope gain will need to be advanced. A 1-microsecond pulse will not be reproduced with a flat top, even in a high-performance video amplifier. A good 1-microsecond pulse display is shown in Fig. 82B. Note that a horizontal-sync pulse (Fig. 83) has a width of about 5 microseconds. Since the rise time of a horizontal-sync pulse as transmitted by a TV station is comparaitvely slow, it is expected that the top will be rounded off and that there will be little or no overshoot and ringing. Note that there is a rule of thumb which states that reasonably good reproduction of a pulse requires that the amplifier have a bandwidth of 2/T, where T is the width of the pulse. For example, a 1-microsecond pulse requires a bandwidth of at least 2 mc.



(A) 100-μs pulse width.



(B) 1-μs pulse width.

Fig. 82. Typical pulse response of a video amplifier.

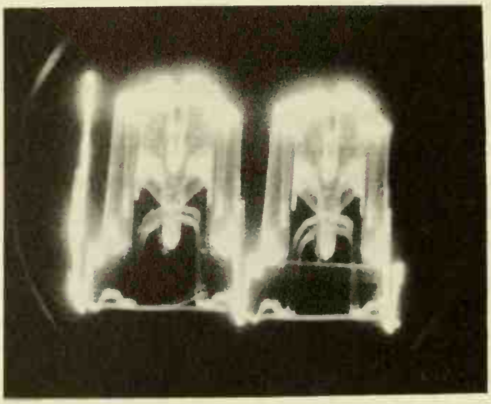
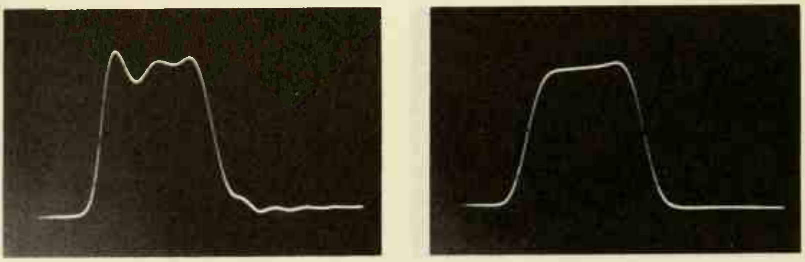


Fig. 83. A horizontal-sync pulse has a width of about 5 μs.

NOTE 22

Observing Equipment Distortion

When making tests with narrow pulses, it is advisable to first feed the pulse signal directly into the scope to observe equipment distortion. There are some pulse generators that have poor waveshape at narrow pulse widths. The scope might also tend to ring on narrow pulses. Any equipment distortion must be taken into account when evaluating the pulse response of a video amplifier. A correctly terminated output cable must also be used with a fast-rise pulse generator to avoid distortion. For example, Fig. 84 shows the result of feeding a 0.1-microsecond pulse directly into the scope, with and without a correctly terminated output cable. Unless good-quality equipment is used, more distortion can be caused by the generator and scope than by the video amplifier under test.



(A) 0.1-μs pulse, output cable unterminated.

(B) 0.1-μs pulse, output cable properly terminated.

Fig. 84. Checking equipment for distortion.

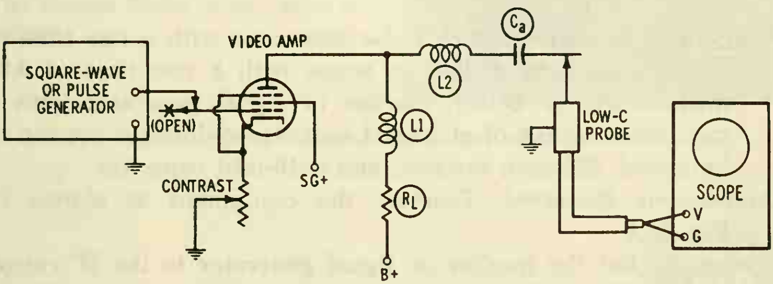
To Check the Plate-Load Circuit of a Video Amplifier

Equipment: Square-wave or pulse generator with a rise time of 0.08 microsecond or better, oscilloscope with rise time of 0.08 microsecond or better, and video amplifier to be tested.

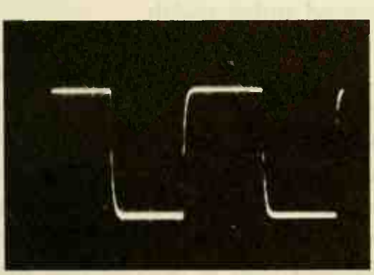
Connections Required: Connect the equipment as shown in Fig. 85A.

Procedure: Observe the pulse or square-wave display on the scope screen at suitable test frequencies, such as a 100-kc repetition rate for a square wave or a 1-microsecond pulse width for a pulse signal. Other repetition rates or pulse widths can also be used, if desired. Figs. 85B and C illustrate typical square-wave responses at 25 kc and 250 kc.

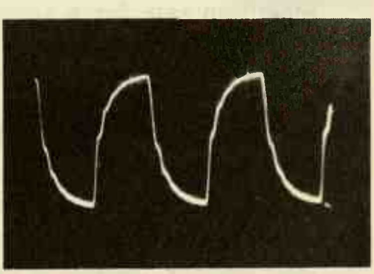
Evaluation of Results: The amount of rounding of the 250-kc square wave seen in Fig. 85C is typical of economy-type video amplifiers. A substantially greater amount of rounding, or excessive overshoot and ringing, points to a defect in the



(A) Test setup.



(B) 25-kc square-wave response.



(C) 250-kc square-wave response.

Fig. 85. Checking plate-load circuit of video amplifier.

plate-load circuit. For example, off-value or defective peaking coils (L1 or L2), or an off-value plate-load resistor (R_L) will result in excessive square-wave distortion. The rise time of the reproduced square wave can be measured with a triggered-sweep scope having calibrated sweeps. The high-frequency cutoff value is given by $f_c = 0.35/T$, where T is the rise time of the square wave (or pulse). Note that the reproduced waveform is not influenced by the video-detector network in Fig. 85A, because the test signal is applied directly to the grid of the video-amplifier tube.

U45

To Check the Response of the Video-Detector Load Circuit

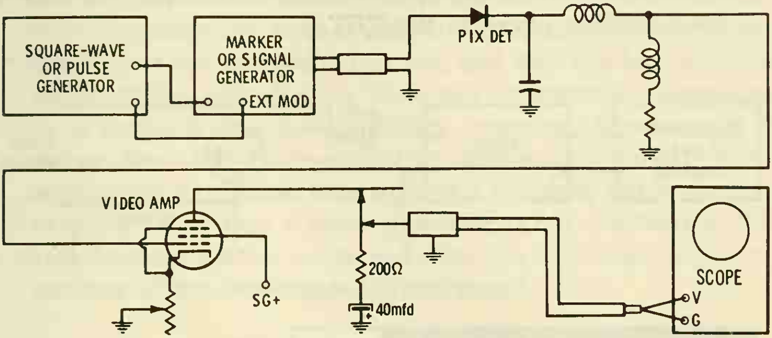
Equipment: Square-wave or pulse generator with a rise time of 0.08 microsecond or better, scope with a rise time of 0.08 microsecond or better, marker or signal generator with a maximum output of at least 1 volt, video-detector section to be tested, 200-ohm resistor, and a 40-mfd capacitor.

Connections Required: Connect the equipment as shown in Fig. 86A.

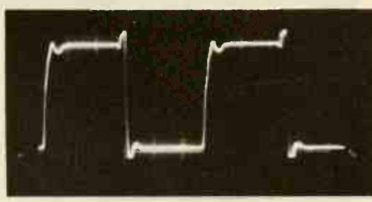
Procedure: Set the marker or signal generator to the IF range, such as 43 mc. Observe the square-wave response at a 100-kc repetition rate for a 1-microsecond pulse width.

Evaluation of Results: The reproduced square wave normally shows some overshoot, which may be accompanied by slight ringing. This is due to the common practice of designing video-detector circuits with a small amount of high-frequency peaking. Excessively distorted square or pulse waveforms point to a defect in the video-detector load network, such as defective peaking coils, a defective capacitor, or an off-value load resistor. Note that the 200-ohm load is provided in the plate circuit of the video amplifier in Fig. 86A to give a flat broad-band response. The video-amplifier tube isolates the scope from the video-detector network. Since the gain of the system is less than unity in this test, it is essential to use a marker or signal generator that has a comparatively high

output. The built-in modulator of the generator must have wide-band response, or excessive distortion will result.



(A) Test setup.



(B) Typical 100-kc square-wave response.

Fig. 86. Video-detector load-circuit response check.

U46

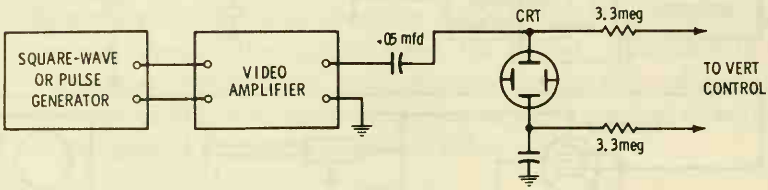
To Check the Response of a Video Amplifier With a Narrow-Band Scope

Equipment: Square-wave or pulse generator with a rise time of 0.08 microsecond or better, oscilloscope, two 0.05-mfd fixed capacitors, and video amplifier to be tested.

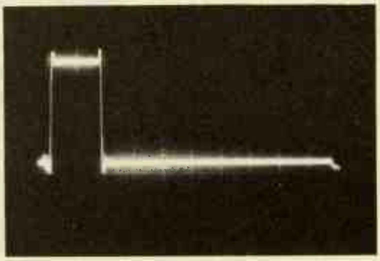
Connections Required: Couple the output from the video amplifier to one of the CRT vertical plates and couple the other vertical plate to ground, as shown in Fig. 87A.

Procedure: Display the square-wave or pulse response on the scope screen in the usual manner. If difficulty is encountered in synchronizing the pattern, use the external-sync function of the scope.

Evaluation of Results: The reproduced waveshape is independent of the vertical-amplifier characteristics, since the high-level signal output from the video amplifier is coupled directly to the deflection plates of the CRT.



(A) Test setup.



(B) 10-μs pulse display.

Fig. 87. Checking video-amplifier response with a narrow-band scope.

U47

To Check a Low-Frequency Compensation Circuit in a Video Amplifier

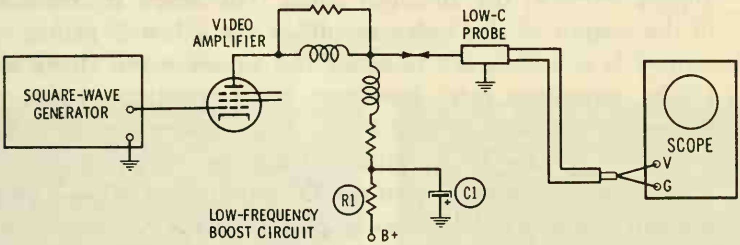
Equipment: Square-wave generator, oscilloscope, and video amplifier to be tested.

Connections Required: Connect the equipment as shown in Fig. 88A.

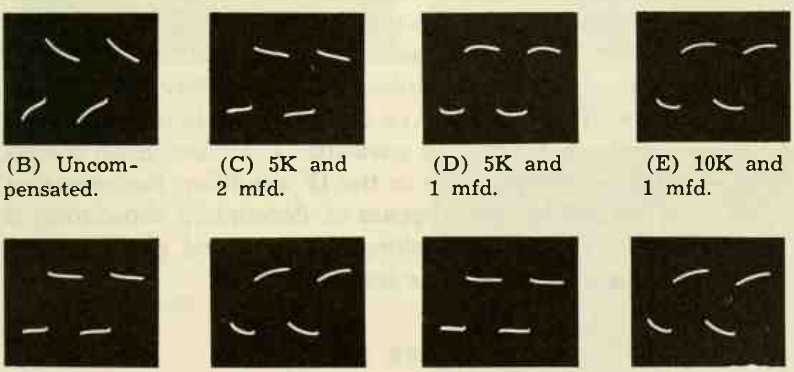
Procedure: Adjust the R and C values in the low-frequency compensating circuit and observe the 60-cycle square-wave reproduction.

Evaluation of Results: The optimum R and C values for the low-frequency compensation (boost) circuit are those that pro-

vide the best 60-cycle square-wave reproduction. In the examples shown (Figs. 88B through I), the optimum values are 15k and 2 mfd. While it is impossible to obtain 100 percent compensation with a simple RC circuit, a marked improvement can be made. You will find that the best 60-cycle square-wave reproduction does not necessarily correspond to a perfectly flat low-frequency response. However, it is better, from the standpoint of picture quality, to have good square-wave response than to have a perfectly flat frequency response. Note that a pulse generator is not practical in this test, because we are concerned with the low-frequency components of the nonsinusoidal test signal.



(A) Test setup.



(B) Uncompensated. (C) 5K and 2 mfd. (D) 5K and 1 mfd. (E) 10K and 1 mfd.

(F) 10K and 2 mfd. (G) 15K and 1 mfd. (H) 15K and 2 mfd. (I) 20K and 1 mfd.

Fig. 88. Checking low-frequency compensation in a video amplifier.

To Make a Square-Wave Test of the IF-Video Amplifier Sections

Equipment: Square-wave generator and scope with rise time of 0.08 microsecond or better, marker or signal generator with wide-band external-modulation function, and TV receiver to be tested.

Connections Required: Connect the equipment as shown in Fig. 89A. The output from the square-wave generator is connected to the external-modulation terminals of the marker or signal generator, and the IF-input cable is unplugged from the RF tuner; the output from the marker or signal generator is fed into the IF-input cable. The scope is connected to the output of the video amplifier via a low-C probe.

Procedure: It is customary to make the square-wave check at a 100-kc repetition rate; however, other repetition rates can be used, such as 1 kc and 1 mc. Avoid overmodulation and overdrive of the IF amplifier. Tune the generator to the picture-carrier frequency of the IF amplifier. A 50-volt peak-to-peak signal at the video-amplifier output is satisfactory.

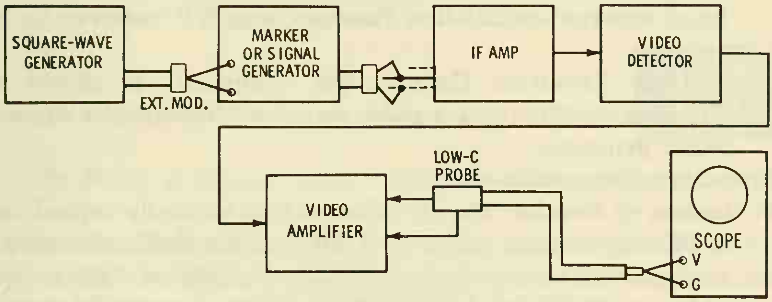
Evaluation of Results: The square-wave reproduction at a 100-kc repetition rate will be noticeably integrated. Rise time of the leading edge should be about 0.1 microsecond. If a substantially slower rise time is measured, it is indicated that the bandwidth of the IF amplifier, video amplifier, or both, is too narrow. The square-wave reproduction is normally free from overshoot, ringing, or parasitic oscillation. Such distortion points to regeneration in the IF amplifier. Regeneration is often caused by open bypass or decoupling capacitors; it can also be caused by peaking the grid and plate circuits of a stage too near the same frequency.

NOTE 23

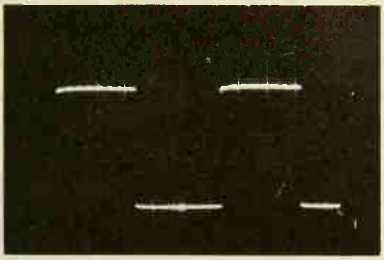
Square-Wave Signal Cannot Be Directly Applied to IF Amplifier

We cannot apply a square-wave signal directly to the IF amplifier as done to a video amplifier because an IF amplifier is basically different. Although a video amplifier has a bandpass from 60 cps to 4 mc, an IF amplifier has a bandpass from 42.75 mc to 45.75 mc, for example. This is a *bandwidth* of 3 mc; however, this bandwidth is centered on 44.25 mc. In other words, an IF amplifier is designed to pass a video signal that

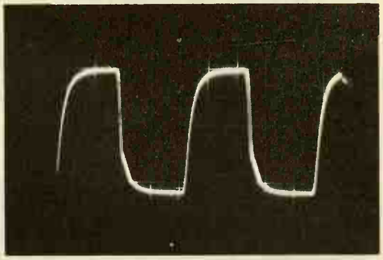
is modulated on a 42.75-mc sine wave. Therefore, to make a square-wave test by feeding the signal into the IF amplifier, we must modulate the square-wave signal on the 42.75-mc picture carrier.



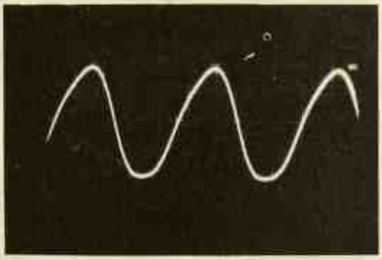
(A) Test setup.



(B) 1-kc waveform.



(C) 100-kc waveform.



(D) 1-mc waveform.

Fig. 89. Square-wave test of IF and video amplifier.

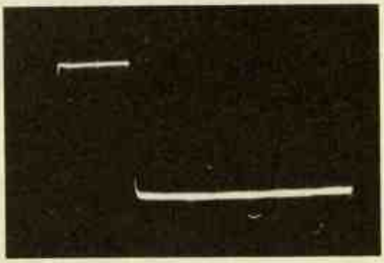
To Make a Pulse Test of the IF-Video Amplifier Sections

Equipment: Pulse generator and scope with rise time of 0.08 microsecond or better, marker or signal generator with wide-band external-modulation function, and TV receiver to be tested.

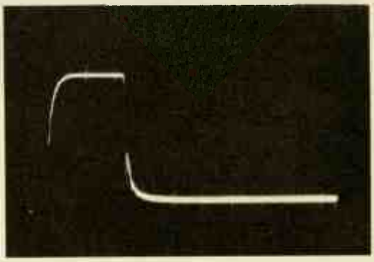
Connections Required: Connect the equipment as shown in Fig. 89A (U48), using a pulse generator instead of a square-wave generator.

Procedure: Same as in U48.

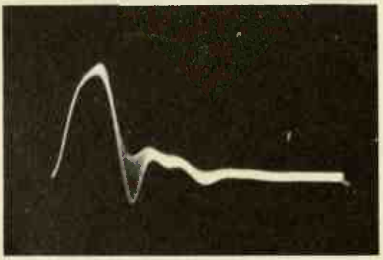
Evaluation of Results: The IF-video section normally reproduces a 100-microsecond pulse with little or no visible distortion; a 10-microsecond pulse is normally reproduced with noticeable integration; a 1-microsecond pulse is normally passed at reduced amplitude and is rounded off. (See Fig. 90). Substantial distortion of a 100-microsecond pulse points to narrow bandwidth in the IF and/or video amplifier; the same condition is indicated by excessive integration of a 10-microsecond pulse. Overshoot, ringing, or parasitic oscillation points to regeneration in the IF amplifier, or misalignment.



(A) 100-microsecond pulse width.



(B) 10-microsecond pulse width.



(C) 1-microsecond pulse width.

Fig. 90. Typical pulse response of IF-video amplifier sections.

A tendency to parasitic oscillation is seen in the 1-microsecond–pulse pattern in Fig. 90C. Note the "bulge" that follows the trailing edge of the pulse, and the irregularity in the base line following the "bulge."

U50

To Make a Square-Wave Test of an IF Amplifier

Equipment: Square-wave generator with a rise time of 0.08 microsecond or better, scope with a rise time of 0.08 microsecond or better, and the IF amplifier to be checked.

Connections Required: The plan of connections is shown in Fig. 91A. Output from the square-wave generator is used to modulate a marker generator or a signal generator. In turn, the modulated output from the marker or signal generator is fed into the IF input cable for the IF amplifier. The scope is connected by a low-C probe to the output of the video detector.

Procedure: It is customary to make a square-wave test at a repetition rate of 100 kc. However, higher or lower repetition rates can be used, if desired. Observe the reproduced square waves on the scope screen. Be sure to tune the marker generator or signal generator accurately to the picture-carrier frequency specified for the IF amplifier.

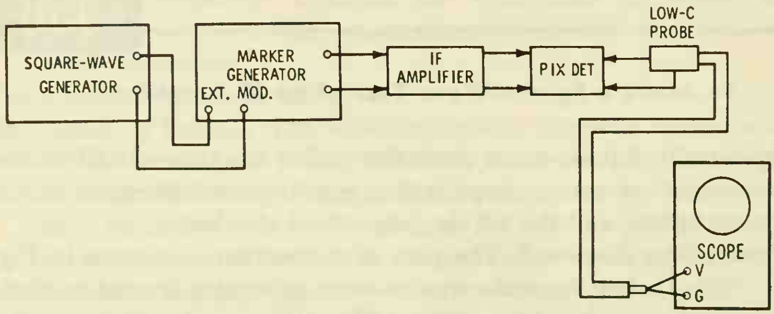
Evaluation of Results: Square-wave responses for an economy-type IF amplifier are illustrated in Figs. 91B through E. In case excessive distortion is noted, it is indicated that the IF amplifier is misaligned or otherwise defective. In such a case, a sweep-frequency check should be made.

NOTE 24

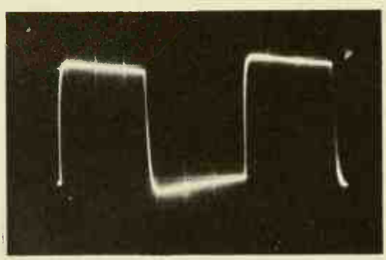
Wide-Band Modulators

It is essential to use a marker generator or signal generator that has a wide-band modulator when making square-wave tests of TV IF amplifiers. Otherwise, the modulated output will be distorted, and the deficiency will be falsely charged to the IF amplifier. Some test-equipment

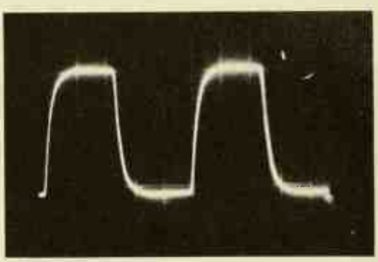
manufacturers provide modulator boxes for use in color-TV tests. These devices provide wide-band modulation and are suitable for use in square-wave tests. Better-quality marker generators usually have built-in wide-band modulators. Lab-type signal generators also have wide-band built-in modulators. However, most ordinary service-type AM signal generators have only audio-frequency modulating facilities.



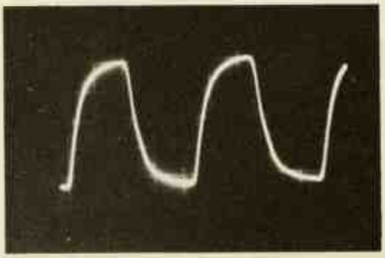
(A) Test setup.



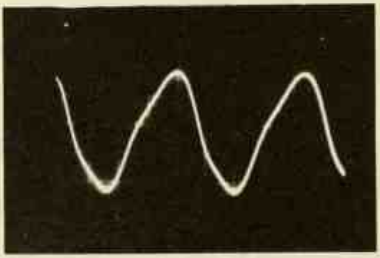
(B) 25-kc waveform.



(C) 100-kc waveform.



(D) 250-kc waveform.



(E) 1-mc waveform.

Fig. 91. IF amplifier square-wave tests.

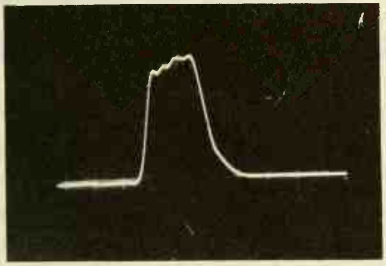
To Make a Pulse Response Test of a TV IF Amplifier

Equipment: Pulse generator with a rise time of 0.08 microsecond or better, scope with a rise time of 0.08 microsecond or better, marker generator or signal generator with built-in wide-band modulator, and the IF amplifier to be checked.

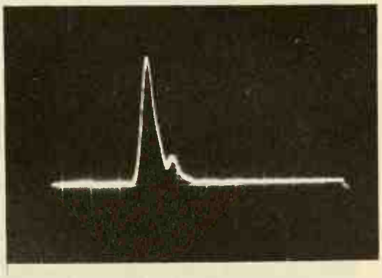
Connections Required: Connect the equipment as shown in U50, using a pulse generator instead of the square-wave generator.

Procedure: Set the pulse generator for a pulse width of 1 microsecond. Other pulse widths can also be used, if desired. Observe the reproduced waveform on the scope screen. Be sure that the marker generator or signal generator is accurately tuned to the picture-carrier frequency specified for the IF amplifier.

Evaluation of Results: Normal pulse reproduction for an economy-type IF amplifier is illustrated in Fig. 92. Excessive waveform distortion points to a misaligned or otherwise defective IF amplifier. In such a case, a sweep-frequency test is desirable.



(A) 1-microsecond pulse width.



(B) 0.1-microsecond pulse width.

Fig. 92. Typical pulse responses of a TV IF amplifier.

NOTE 25

Peaking Can Cause Pulse Distortion

You will find that pulse distortion in an IF amplifier depends on the particular peaking frequencies that are used in successive stages. In other words, if the first stage is peaked to an incorrect frequency, the overall IF response curve might appear normal because of incorrect peaking of the following stages. However, the pulse response will be changed, in spite of the fact that the overall curve shape is normal. This is due

to the change in phase characteristic caused by shifted peaking frequencies. The best peaking frequencies are those that give the best response to narrow pulses.

U52

To Make a Square-Wave Test of the RF-IF Sections

Equipment: Square-wave generator and scope with a rise time of 0.08 microsecond or better, RF marker or signal generator with built-in wide-band modulator, and TV receiver to be tested.

Connections Required: Connect the equipment as shown in Fig. 93A.

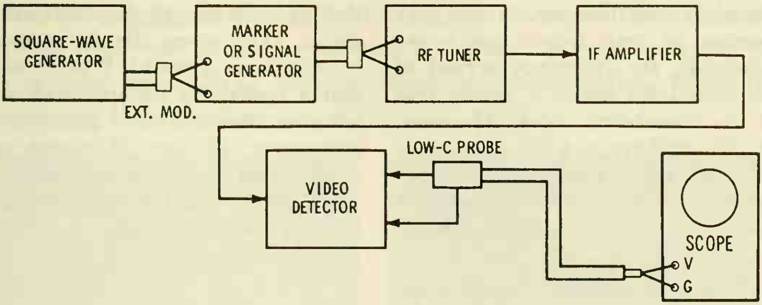
Procedure: Tune the marker or signal generator to the picture-carrier frequency of the channel to which the receiver is set. Avoid overmodulation of the marker or signal generator, which could distort the output by disturbing generator operation. Do not overload the RF and IF amplifiers—a 1-volt p-p signal output from the video detector is satisfactory.

Evaluation of Results: It is customary to make a square-wave test at a repetition rate of 100 kc; however, other repetition rates can be used, if desired. Preshoot may be observed, as seen in the 100-kc and 250-kc photos of Fig. 93B. A small amount of preshoot is normal and does indicate amplifier defects or misalignment. On the other hand, substantial overshoot and ringing are not normally observed; this form of distortion points to regeneration—most likely to occur in the IF amplifier. Noticeable integration of the 100-kc square-wave response is expected; however, excessive integration indicates narrow bandwidth in the IF amplifier, RF amplifier, or both.

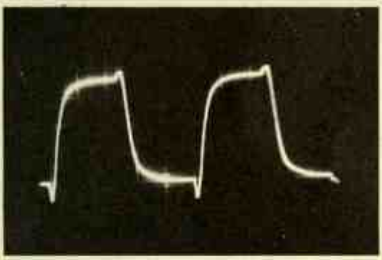
NOTE 26

Basic Amplifier Responses

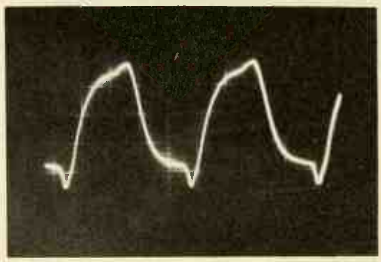
The RF-IF amplifier in a TV receiver has a bandpass that includes only a very small part in the VHF spectrum. Nevertheless, because of the high center frequency of the RF amplifier, this "slice" includes video



(A) Test setup.



(B) 100-kc waveform.



(C) 250-kc waveform.

(D) 1-mc waveform.

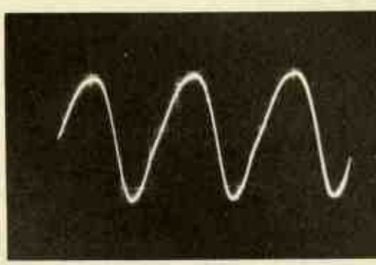
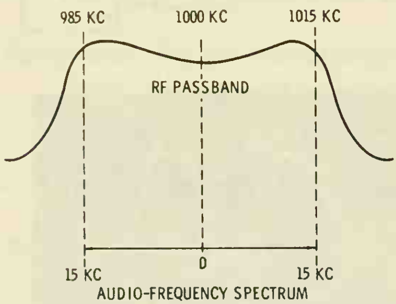


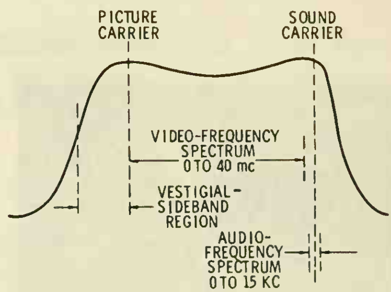
Fig. 93. RF-IF square-wave response of economy-type receiver.

frequencies and audio frequencies. These facts are illustrated in Fig. 94. In the case of an ordinary radio receiver, for example, the RF center frequency might be 1000 kc, with band limits at 965 kc and 1015 kc. This is a *bandwidth* of 20 kc, which passes audio frequencies from 0 to 15 kc that are modulated on a 1000-kc carrier. Again, in the case of a TV receiver, the RF bandwidth is sufficient to pass both video frequencies and audio frequencies that are modulated on the RF carrier. In other words, the basic system design provides for tuning an *extensive series of modulated-RF carriers.* Therefore, it follows that a square-wave test of an RF-IF system can be made only by modulating the square-wave signal on the RF picture-carrier frequency. Since am-

plitude modulation entails the production of both upper and lower sidebands, the frequency spread of the modulated signal is double that of the modulating signal. However, the IF amplifier in a TV receiver is designed for vestigial-sideband reception, which requires only a slightly greater frequency spread than is contained in the modulating signal. (This gives rise to preshoot in square-wave tests.) Finally, note that a modulated square-wave signal gives the same basic information concerning RF- and IF-circuit response that a direct square-wave signal gives concerning video-amplifier response.



(A) Broadcast receiver.



(B) Television receiver.

Fig. 94. Frequencies in the RF bandpass.

U53

To Make a Pulse Test of the RF-IF Sections

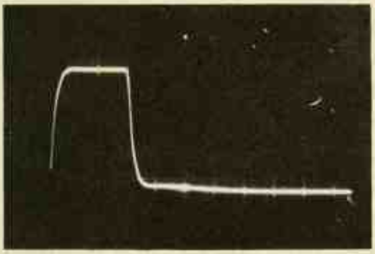
Equipment: Pulse generator and scope with a rise time of 0.08 microsecond or better, RF marker or signal generator with built-in wide-band modulator, and TV receiver to be tested.

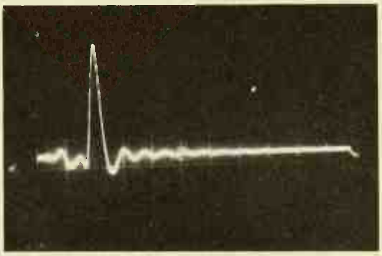
Connections Required: Connect the equipment as shown in Fig. 93A (U52), using a pulse generator instead of a square-wave generator.

Procedure: Same as in U52.

Evaluation of Results: The RF-IF sections normally pass a 1-microsecond pulse with a small amount of integration. (See Fig. 95.) A 0.1-microsecond pulse is passed at reduced amplitude and is rounded off. Excessive integration of a 1-microsecond pulse points to subnormal bandwidith in the RF and/

or IF amplifiers. Normally, little or no overshoot and ringing are observed. Substantial overshoot and ringing point to a peaked response of the amplifiers, or regeneration (usually in the IF amplifier).





(A) 1-microsecond pulse width. (B) 0.1-microsecond pulse width.

Fig. 95. Typical pulse responses of RF-IF amplifier sections.

U54

To Check the Square-Wave Response of the RF Tuner, IF Amplifier, and Video Amplifier

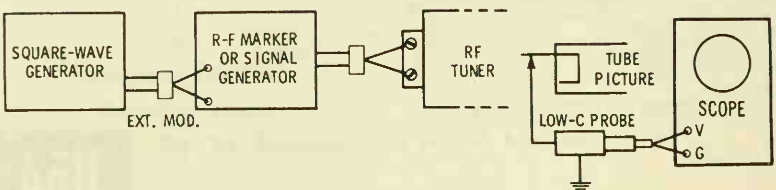
Equipment: Square-wave generator and scope with rise time of 0.08 microsecond or better, RF marker or signal generator with wide-band built-in modulator, and TV receiver to be tested.

Connections Required: Connect the equipment as shown in Fig. 96A. Since the low-capacitance probe has an input capacitance, typically 7 mmf, it is good practice to make reasonable compensation for this capacitance. If the socket is unplugged from the picture tube, the cathode input capacitance is eliminated.

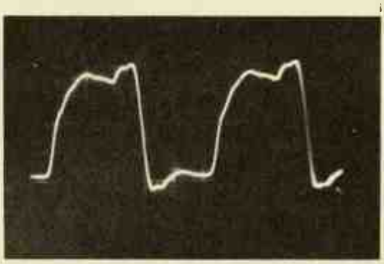
Procedure: Advance the output from the square-wave generator to obtain 100-percent modulation of the RF carrier; this is the most severe test of square-wave response. You can determine easily when 100-percent modulation is reached, because the pattern height does not increase further on the

scope screen with increased output from the square-wave generator. Adjust the output from the marker or signal generator for about 50-volts p-p output from the TV receiver. Tune the generator accurately to the RF picture-carrier frequency.

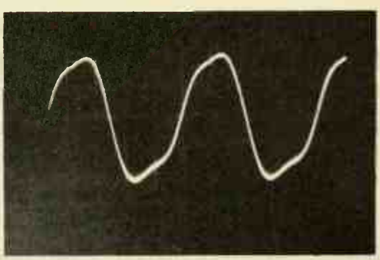
Evaluation of Results: Typical responses for square waves at 100-kc and 250-kc repetition rates are shown in Figs. 96B and C for an economy-type receiver. A deluxe receiver will probably provide noticeably better square-wave response when properly aligned. In particular, the leading edge will rise faster, and cornering will be less rounded. The system bandwidth is found from the rise time of the reproduced square wave; the high-frequency cutoff occurs at a frequency equal to $0.35/T$, where T is the rise time.



(A) Test setup.



(B) 100-kc waveform.



(C) 250-kc waveform.

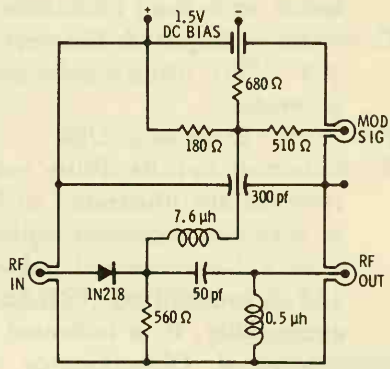
Fig. 96. Check of overall square-wave response of TV receiver.

NOTE 27

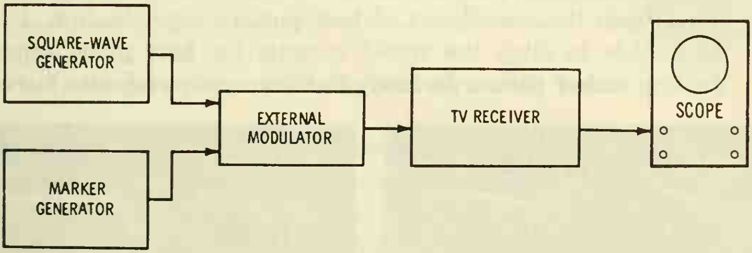
Use of External Modulation

If your marker or signal generator does not have a wide-band built-in modulator, you can use an external modulator with the configuration

shown in Fig. 97. A semiconductor diode is used, biased to a suitable point on its forward characteristic. Since the AC path of operation on the characteristic is nonlinear, the RF carrier is amplitude modulated. For 100-percent modulation, the amplitude of the square-wave signal is adjusted to drive the diode to cutoff on positive peaks. Thus, the diode operates as an electronic switch, turning the RF carrier on and off at the repetition rate of the square-wave signal.



(A) High-quality external modulator.



(B) Test setup.

Fig. 97. External modulator for square-wave test.

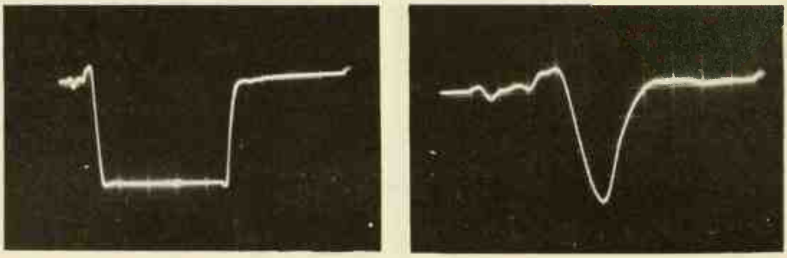
To Make a Pulse Response Test of the RF Tuner, IF Amplifier, and Video Amplifier

Equipment: Pulse generator and scope with rise time of 0.08 microsecond or better, RF marker or signal generator with wide-band built-in modulator (or supplemented by an external wide-band modulator), and TV receiver to be tested.

Connections Required: Connect the equipment as shown in Fig. 96A (U55), using a pulse generator instead of a square-wave generator.

Procedure: Same as in U55.

Evaluation of Results: Pulse responses for an economy-type TV receiver are illustrated in Fig. 98. A 10-microsecond pulse is normally displayed without substantial distortion. However, a 1-microsecond pulse is passed at reduced amplitude and is rounded off. If a 10-microsecond pulse is integrated appreciably, it is indicated that the receiver bandwidth is subnormal. Objectionable overshoot and ringing point to peaked response (usually in the IF amplifier) or regeneration. From the standpoint of best picture reproduction, it is preferable to align the tuned circuits for best pulse reproduction rather than a perfectly flat frequency-response curve.



(A) 10-microsecond pulse width. (B) 1-microsecond pulse width.

Fig. 98. Check of overall pulse response of a TV receiver.

STEREO-FM UNIT AND SYSTEM TESTS

U56

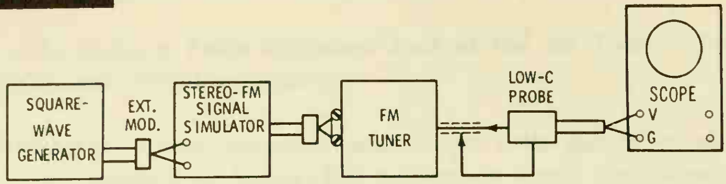
To Make a Square-Wave Test of an FM Tuner

Equipment: Square-wave generator, stereo-FM signal simulator (stereo-FM multiplex generator with built-in modulator), scope, and FM tuner to be tested.

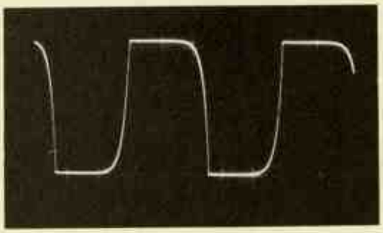
Connections Required: Connect the equipment as shown in Fig. 99A.

Procedure: Set the square-wave generator to 2-kc repetition rate for standard test. Tune the FM receiver to the RF output frequency of the FM generator (such as 100 mc). Advance the output from the square-wave generator to obtain approximately 1-volt p-p output from the FM tuner.

Evaluation of Results: We normally observe noticeable integration of a 2-kc square wave. Excessive integration points to misalignment of the FM tuner, with subnormal bandwidth. Preshoot or overshoot will be observed if the FM tuner is not tuned to the center frequency of the applied RF signal—if such distortion cannot be eliminated by proper tuning, the alignment of the RF circuits or the discriminator, or both, is incorrect.



(A) Test setup.



(B) 2-kc waveform.

Fig. 99. Square-wave test of FM tuner.

NOTE 28

Frequency Modulation by Square Waves

Frequency modulation of an RF carrier by a square wave is depicted in Fig. 100. Note that the amplitude of the RF carrier remains unchanged—the square wave changes the frequency of the carrier. As the square wave rises and falls, the carrier frequency changes abruptly. The carrier has one frequency corresponding to the positive-peak voltage of the square wave, and another frequency corresponding to the negative-peak voltage. The amount of the frequency change depends on the amplitude of the square wave. If the amplitude of the square wave is increased, there is a greater amount of frequency change; this is called the *deviation* of the RF carrier.

To explain 100-percent modulation in an FM system, let us first review the same condition for an AM wave. A 100-percent modulation exists when the amplitude of the carrier varies between zero and twice its normal unmodulated value. However, in frequency modulation, 100-percent modulation has a different meaning. A modulation of 100 percent simply means that the carrier is deviated in frequency by the full permissible amount. For example, an 88-mc FM signal has 100-percent modulation when the square-wave signal deviates the carrier 75 kc above and 75 kc below the 88-mc value—this deviation is the standard permissible frequency swing. For 50-percent modulation, the frequency would be deviated 37.5 kc above and below 88 mc.

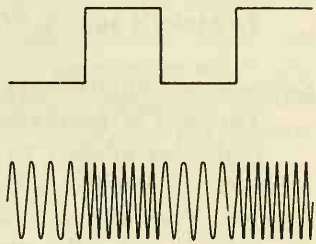


Fig. 100. Frequency modulation of an RF carrier by a square wave.

U57

To Make a Pulse Test of an FM Tuner

Equipment: Pulse generator, FM stereo-signal simulator (FM stereo-multiplex generator with built-in modulator), scope, and FM tuner to be tested.

Connections Required: Connect the equipment as shown in Fig. 99A (U56), using a pulse generator instead of a square-wave generator.

Procedure: Same as in U56.

Evaluation of Results: In normal operation we observe a flat-topped pulse reproduction until the pulse width is reduced to about 10 microseconds. Then, the flat top disappears and the leading edge meets the trailing edge at the peak of the pulse, as seen in Fig. 101. Thus, the pulse has a rounded shape. If the top of the pulse becomes rounded off at pulse widths substantially greater than 10 microseconds, it is indicated that the FM tuner has subnormal bandwidth—either a defective component is present or the tuner needs realignment. Overshoot and ringing are normally absent. If such distortion occurs, check the tuner for an unsymmetrical or peaked RF response curve.

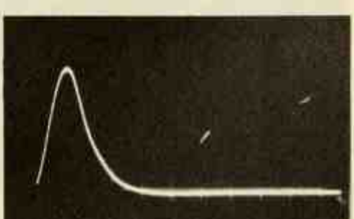


Fig. 101. Response of an FM tuner to a narrow pulse (10-microsecond pulse width).

To Make a Square-Wave Test of a Stereo-Multiplex Adapter

Equipment: Square-wave generator, stereo-FM signal simulator (stereo-FM generator with built-in modulator), scope, and multiplex adapter to be tested.

Connections Required: Connect the equipment as shown in Fig. 102. Feed the square-wave signal into the external-modulation posts of the stereo generator; feed the composite audio signal into the multiplex adapter; connect the scope to the right output of the adapter.

Procedure: Switch the stereo generator to the left output; adjust the separation control of the multiplex adapter for minimum output; then, switch the stereo generator back to the right output. Finally, connect the scope to the left output of the adapter and repeat the procedure.

Evaluation of Results: Both 60-cps and 2-kc square waves are passed with noticeable distortion, as exemplified in Fig. 103A and B. Better reproduction of the 60-cycle square wave, in particular, is obtained with the generator and adapter switched to mono operation—this results from bypassing the

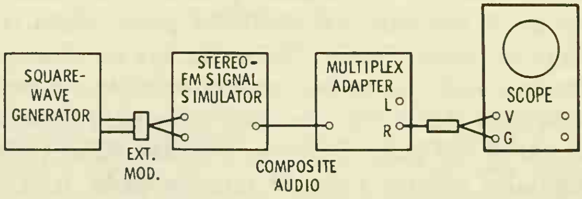
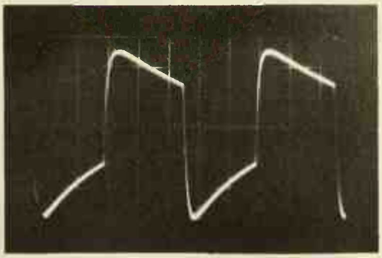
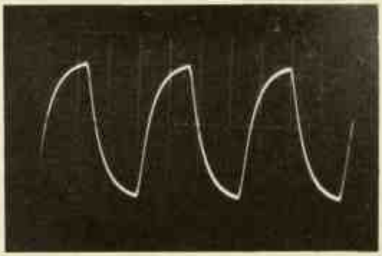


Fig. 102. Square-wave test of stereo-multiplex adapter.



(A) 60-cps waveform.



(B) 2-kc waveform.

Fig. 103. Stereo multiplex-adapter waveform.

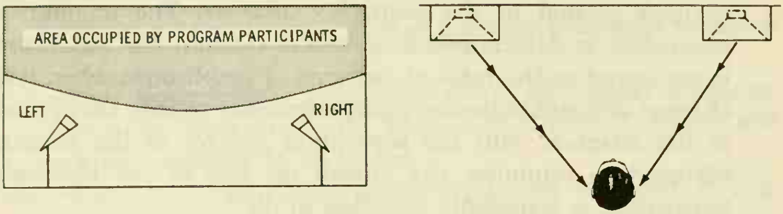
sampler section in the multiplex adapter. The amount of *separation* is determined in stereo operation; the separation is measured as the ratio of patterns of amplitudes when left-channel and right-channel audio composite signals are applied to the adapter, with the separation control of the adapter adjusted to minimize the output on one of the channels. Separation is commonly specified in db.

NOTE 29

Basic Principle of Multiplex Operation

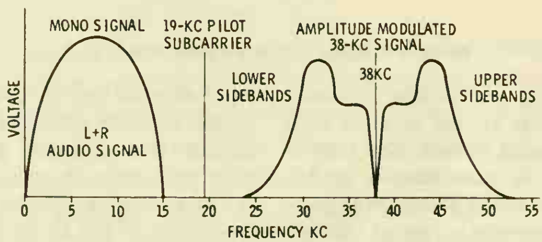
Beginners are sometimes confused by the various circuit sections of a stereo-multiplex system. The fundamental plan is quite simple, as depicted in Fig. 104. A stereo-multiplex generator provides a signal similar to that generated by a broadcast station, except that the output has 1-kc sine-wave modulation when the internal audio oscillator is used; or, the output has square-wave or pulse modulation when externally modulated by a square-wave or pulse generator. The composite audio signal is diagrammed in Fig. 105A. The L + R signal consists of the mixed outputs of the left and right channels. The modulated 38-kc signal consists of the L — R signal modulated on a suppressed 38-kc subcarrier. The L — R signal consists of the left-channel signal mixed in reverse polarity (phase) with the right-channel signal. To optimize the signal-to-noise ratio, the 38-kc subcarrier is suppressed and a 19-kc pilot subcarrier is used in its place.

The multiplex adapter doubles the frequency of the 19-kc pilot subcarrier and reinserts the missing 38-kc subcarrier. Also, the adapter samples the L + R and L — R signals alternately at a 38-kc rate and recovers the left-channel and right-channel signals by addition and subtraction. In turn, we test the left-channel and right-channel outputs, as shown in Fig. 105B. If the generator is set for right-channel output and the separation control of the adapter is adjusted for minimum left-channel output, full output is normally found from the right channel and very little output from the left channel. Manufacturers rate their multiplex adapters for separation in decibels.

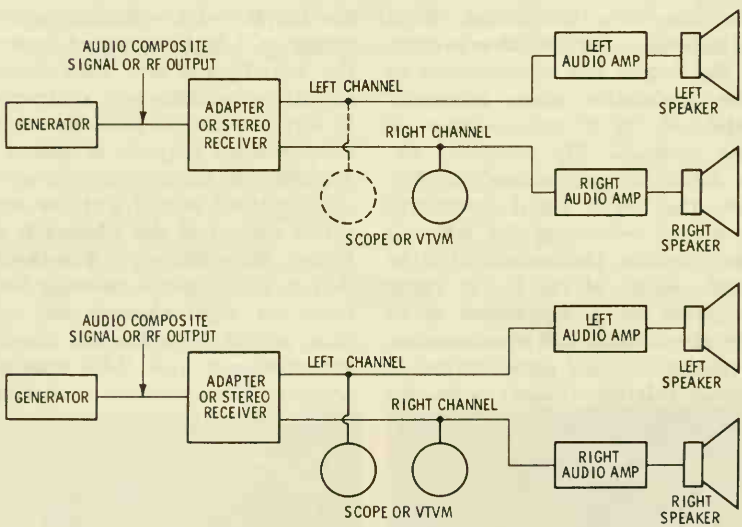


(A) Microphone placement at studio. (B) Speaker placement at receiver.

Fig. 104. Plan of a stereo-multiplex system.



(A) Composite audio signal.



(B) Test of a stereo-multiplex adapter.

Fig. 105. Signal processing in a stereo-multiplex system.

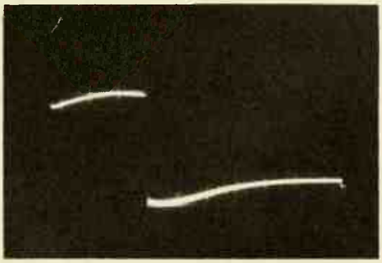
To Make a Pulse Response Test of a Stereo-Multiplex Adapter

Equipment: Pulse generator, stereo-FM signal simulator (stereo-FM multiplex generator with built-in modulator), scope, and multiplex adapter to be tested.

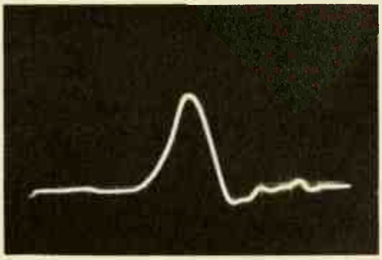
Connections Required: Connect the equipment as shown in U58, using a pulse generator instead of a square-wave generator.

Procedure: Observe the response of the multiplex adapter for a 1000-microsecond pulse and for a 100-microsecond pulse. Check both left-channel and right-channel outputs with the separation control of the adapter set for maximum rejection of the channel output that is not under test.

Evaluation of Results: A 1000-microsecond pulse may be reproduced with some tilt and curvature, as seen in Fig. 106A. When the pulse width is reduced to 100 microseconds, the reproduced pulse will be rounded off. Serious distortion points to a defect in the adapter, such as defective capacitors or semiconductor diodes. Poor separation also indicates a faulty component in the adapter.



(A) 100-microsecond pulse width.



(B) 100-microsecond pulse width.

Fig. 106. Pulse response of a stereo-multiplex adapter.

NOTE 30

Operation of Multiplex Decoder

The configuration for a typical multiplex decoder (multiplex adapter) is seen in Fig. 107. The composite audio signal is amplified by transistors X1 and X2; transformer T1 is tuned to 19 kc and picks out the pilot subcarrier. Further amplification is provided by X3. A tap is taken from the primary of T2, which feeds the 19-kc pilot subcarrier to transistor X4. The base and emitter of X4 are tied to zero reference by R13—hence, X4 operates as a rectifier. Output from X4 is fed to the stereo indicator. Thus, the stereo-indicator lamp glows only when a multiplex signal is present.

The 19-kc output from the secondary of T2 is doubled to 38 kc by diodes M1 and M2, which operate in an unfiltered full-wave rectifier circuit. Note that the collector of X1 also feeds a composite audio signal to X6. From the output of X6 the composite audio signal is mixed with the 38-kc subcarrier (subcarrier reinsertion). This is done via X5, which feeds the 38-kc subcarrier to the primary of T4. In turn, the secondary of T4 feeds the 38-kc subcarrier to the semiconductor-diode bridge. Composite audio is fed to the bridge from X6.

Since diodes M3 through M10 conduct in only one direction, they operate as electronic switches in response to positive and negative half-cycles of the 38-kc subcarrier. In turn, the L + R and L − R components of the composite audio signal are separated and fed to transistors X7 and X9. Addition and subtraction occur in this circuitry, with the result that transistor X8 delivers an R signal and transistor X10 delivers an L signal. These L and R audio signals, in turn, are fed to the audio amplifiers that drive the speakers.

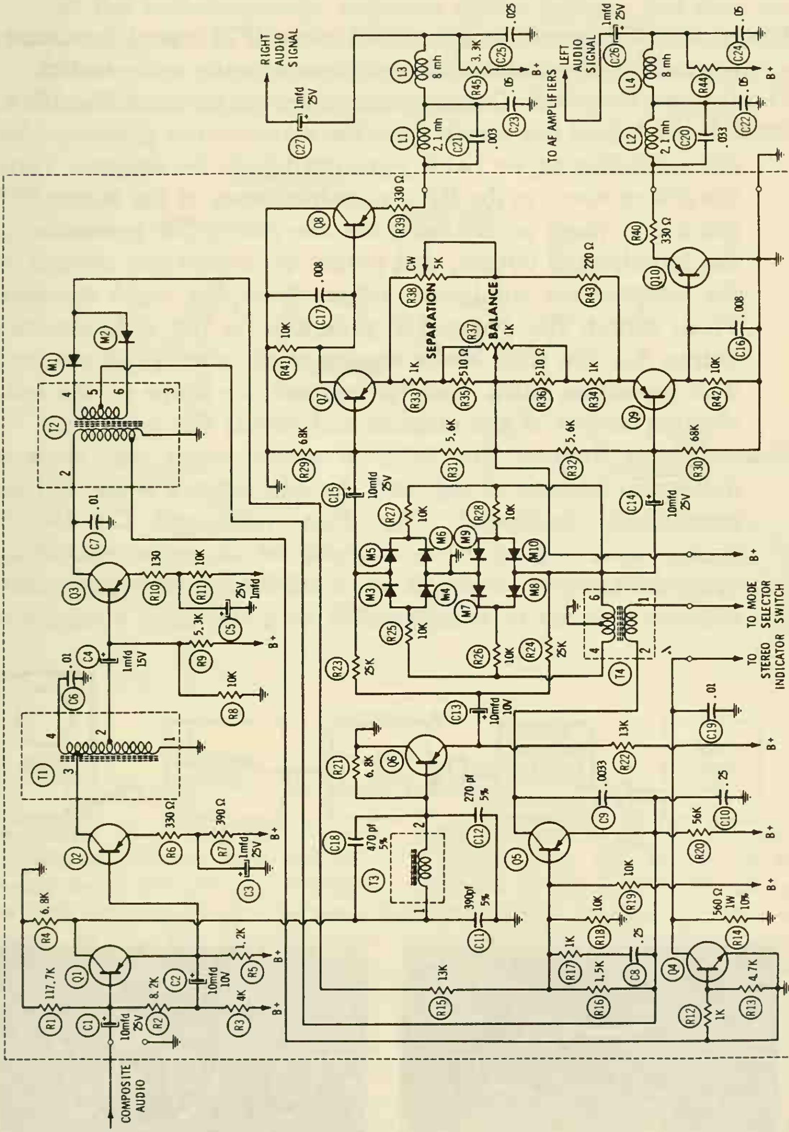


Fig. 107. Multiplex decoder uses a total of 10 transistors and 10 signal diodes.

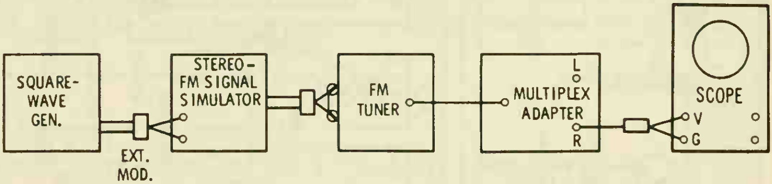
To Make a Square-Wave Test of an FM Tuner and a Stereo-Multiplex Adapter

Equipment: Square-wave generator, stereo-FM signal simulator, scope, and FM tuner and multiplex adapter to be tested.

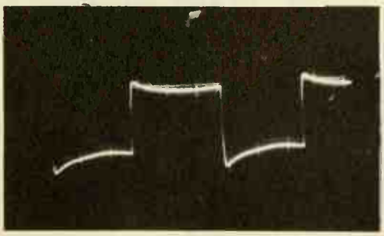
Connections Required: Connect equipment as shown in Fig. 108A.

Procedure: Adjust the output from the square-wave generator for normal deviation, or 1-volt p-p output from the adapter. Tune the FM receiver to the RF center frequency of the stereo-FM generator (such as 100 mc). Set the stereo-FM generator to the left-channel output, and adjust the separation control of the adapter for minimum output from the right channel. Then, switch the stereo-FM generator to the right-channel output for the test. Make square-wave tests at 60-cps and 2-kc repetition rates. Finally, connect the scope to the left-channel output of the adapter and repeat the procedure.

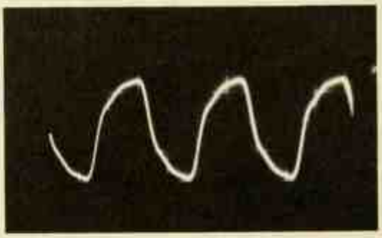
Evaluation of Results: The 60-cycle square wave may show a noticeable amount of sag, and the 2-kc square wave will be appreciably integrated. (See Figs. 108B and C.) Better square-wave reproduction is observed on mono operation, since the sampler section is not used. Excessive square-wave distortion points to misalignment or a defective component



(A) Test setup.



(B) 60-cps waveform.



(C) 2-kc waveform.

Fig. 108. Square-wave test of an FM tuner and multiplex adapter.

in the FM tuner, or a defect in the multiplex adapter. Recall that the rise time of the reproduced square wave depends on the high-frequency response of the system, and that the tilt depends on the low-frequency response. In other words, the regions of high-frequency and low-frequency information are located as depicted in Fig. 109.

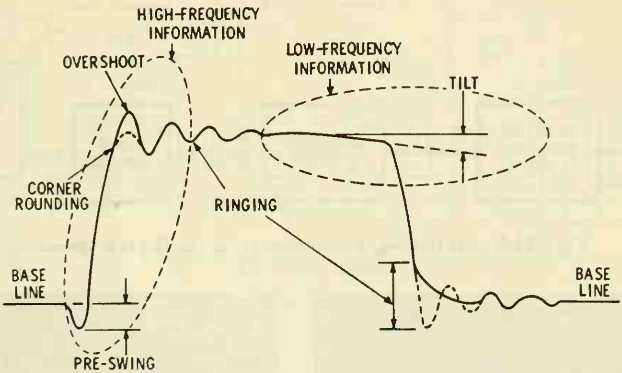


Fig. 109. Regions of high-frequency and low-frequency information in a square wave.

NOTE 31

Matrixing Operation

A matrix in a multiplex decoder (multiplex adapter) adds and subtracts the L + R and L — R signals to form the L and R audio signals, as shown in Fig. 110. The FM tuner feeds the RF signal to the discriminator. In turn, the output from the discriminator consists of the L + R audio signal and sidebands of the L — R signal. Since the sidebands of the L — R signal extend from 23 kc to 53 kc, the amplifiers following the discriminator reject the L — R sidebands, and pass only the 0-15 kc L + R signal. However, the 23- to 53-kc bandpass circuit accepts the L — R signal, and rejects the L + R signal.

Output from the 23- to 53-kc bandpass circuit is demodulated by the amplitude detector, thereby developing the L — R audio signal. Addition of the L + R and L — R signals results in formation of 2L, or the left-channel signal. Next, the L — R signal is passed through a phase inverter which forms a —L +R signal. When L + R is added to —L +R, the result is formation of 2R, or the right-channel audio signal. This is called the matrix method of developing the L and R audio signals.

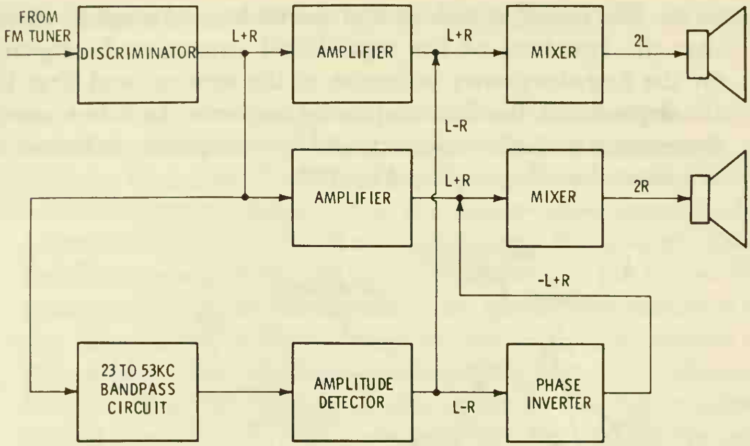


Fig. 110. Matrixing operation in a multiplex decoder.

U61

To Make a Square-Wave Test of a Complete Stereo-FM System

Equipment: Square-wave generator, stereo-FM signal stimulator (stereo-FM generator with built-in modulator), FM tuner, multiplex adapter, audio amplifiers, scope, and suitable load resistors for the amplifiers.

Connections Required: Connect the equipment as shown in Fig. 111A.

Procedure: Same as in U60, except that the treble and bass controls of the amplifiers should be set to provide optimum square-wave reproduction.

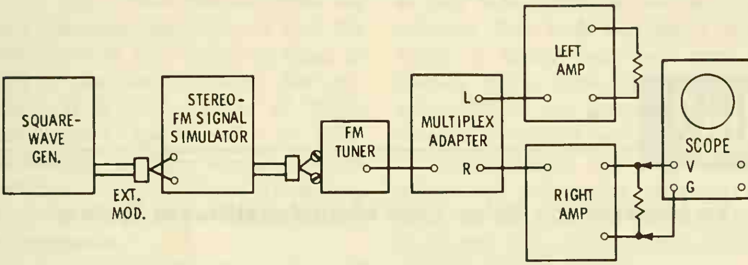
Evalutaion of Results: Typical 60-cps and 2-kc square-wave responses for a moderately priced system are illustrated in Figs. 111B and C. Excessive distortion points to a defective tube, semiconductor diode, transistor, or component. Aside from tubes, capacitors are the most common troublemakers. The high-frequency cutoff of the system is indicated by the

rise time of the reproduced square wave, according to the formula:

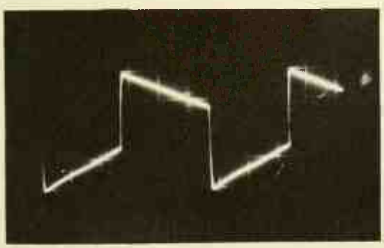
$$f_c = 0.35/T$$

where,

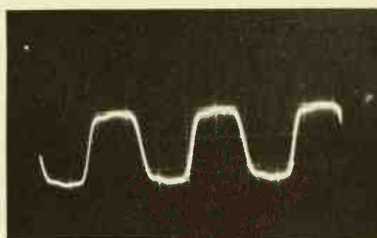
f_c is the frequency at high-frequency cutoff (−3 db down),
T is the rise time of the reproduced square wave.



(A) Test setup.



(B) 60-cps waveform.



(C) 2-kc waveform.

Fig. 111. Square-wave test of a stereo system.

NOTE 32

Switching System of Decoding Samples L + R and L − R Envelopes

When the L + R signal is mixed with the amplitude-modulated L − R signal, a *composite audio signal* is formed. The composite audio waveform has different positive and negative envelopes, as depicted in Fig. 112. The positive envelope consists of the L + R audio signal, and the negative envelope consists of the L − R audio signal. Hence, if the envelopes are sampled at a 38-kc rate by means of electronic-switching action, one output from the electronic switch will consist of the L + R audio signal and the other output will consist of the L − R audio signal. Then, when the two outputs are added, we obtain 2L; when the two outputs are subtracted, we obtain 2R. Thus, the L and R audio signals are recovered to be fed to the left-channel and right-channel speakers.

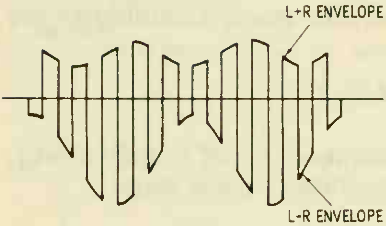


Fig. 112. Positive and negative envelopes carry L + R and L − R modulation.

U62

To Measure the Delay Time of an Amplifier or System

Equipment: Square-wave generator, scope with calibrated sweeps, and amplifier or system to be tested.

Connections Required: Apply the output from the square-wave generator to the amplifier (or system); connect the scope to the load resistor of the amplifier (or system).

Procedure: Adjust the scope controls to expand the leading edge of the reproduced square wave.

Evaluation of Results: The delay time of the amplifier or system is equal to the elapsed time from the start of the leading edge to the 50-percent amplitude point, as depicted in Fig. 113. In general, the delay time increases when the number of amplifier stages is increased. The delay time is a figure of merit; the shorter the delay time, the better is the performance of the amplifier or system. The rise time is also a figure of merit; however, there is no fixed relation between the delay time and the rise time.

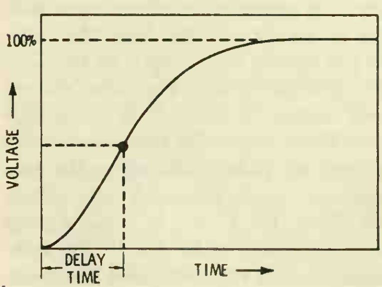


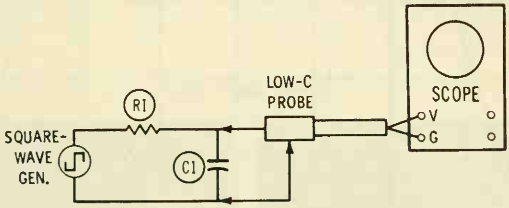
Fig. 113. Delay time of a reproduced square wave.

NOTE 33

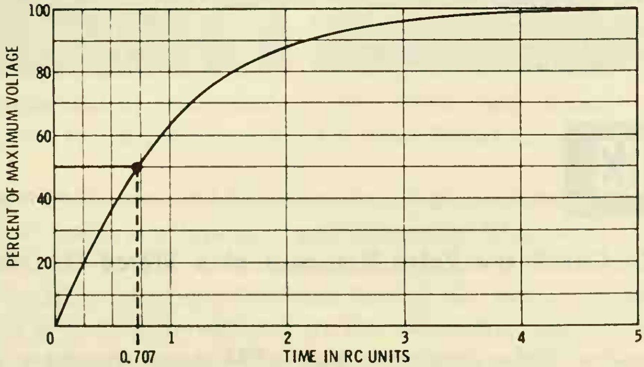
Delay Time of Integrator Circuits

The delay time of a circuit can often be predicted. For example, consider the simple integrator circuit shown in Fig. 114A. From the universal RC time-constant chart, we see that the delay time of the circuit is equal to 0.707 of the time constant. For example, if R has a value of 10,000 ohms and C has a value of 0.001 microfarad, the time constant of the circuit is 10 microseconds. Therefore, the delay time of the circuit is 7.07 microseconds.

Next, consider the delay time of a two-section symmetrical-integrator circuit, depicted in Fig. 115A. We observe that the delay time is equal to two time constants. For example, suppose that each resistance has a value of 10,000 ohms and each capacitor has a value of 0.001 microfarad. Then, the delay time of the integrator circuit will be equal to 20 microseconds. In other words, when two integrator sections are connected in cascade, the delay time is greater than the sum of the delays of the individual sections.



(A) RC-integrator circuit.



(B) Chart.

Fig. 114. The delay of a simple RC integrator is 0.707 of the time constant.

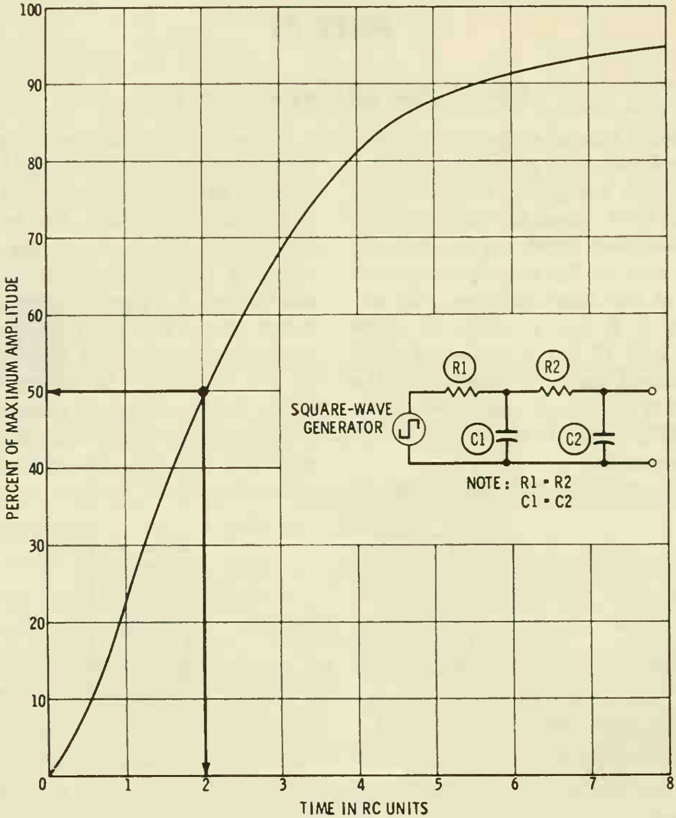


Fig. 115. The delay time of the RC-integrator circuit is equal to two time constants.

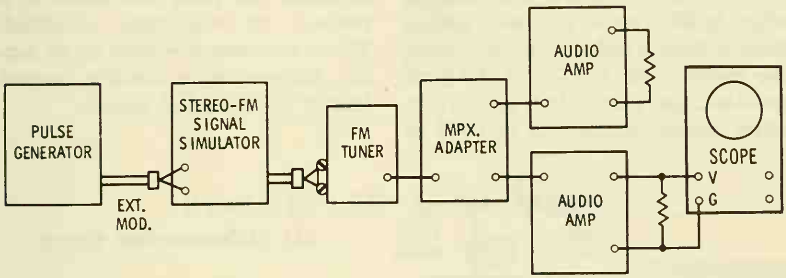
U63

To Check the Pulse Response of a Stereo-FM Multiplex System

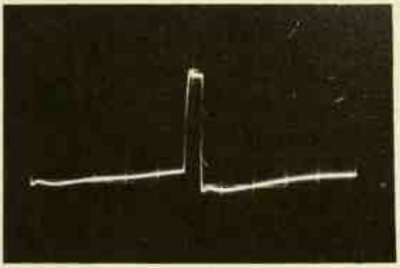
Equipment: Pulse generator, stereo-FM signal simulator (stereo-multiplex generator with built-in external modulator), FM tuner, multiplex adapter, audio amplifiers, load resistors of suitable values, and scope.

Connections Required: Connect the equipment as shown in Fig. 116A.

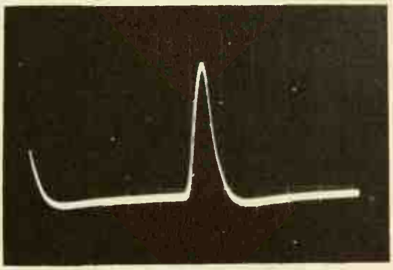
Procedure: Adjust the stereo-FM signal simulator for normal deviation and tune to the frequency of the FM tuner (such as 100 Mc). Adjust the controls of the adapter and audio amplifiers for normal operation. Check the output of each amplifier, in turn, for a 1000-microsecond pulse and a 100-microsecond pulse.



(A) Test setup.



(B) 1000-microsecond pulse width.



(C) 100-microsecond pulse width.

Fig. 116. Typical pulse response of a stereo FM-multiplex system.

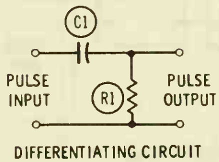
Evaluation of Results: A 1000-microsecond pulse and a 100-microsecond pulse are typically reproduced as illustrated in Fig. 116B and C. The 100-microsecond pulse will be rounded off considerablly, and the base line of the 1000-microsecond pulse will be differentiated at low repetition rates. Slightly better pulse reproduction is normally observed when the adapter is set for mono instead of stereo operation. Excessive distortion points to a defect in the tuner, adapter, or audio amplifier. Individual units can be tested for pulse response,

as previously explained, to localize a defect to a particular unit.

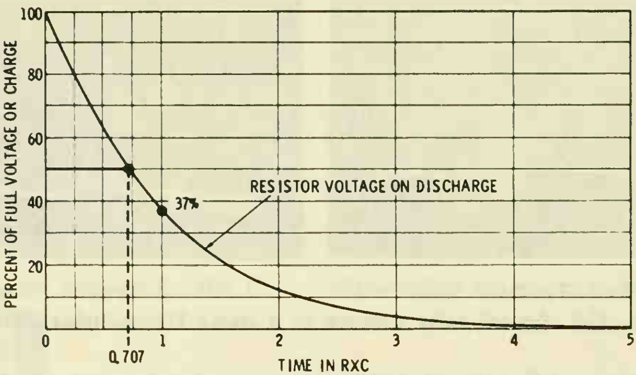
NOTE 34

Width of Differentiated Pulse

The width of a pulse is defined as the elapsed time between the 50 percent-of-maximum amplitude points on the leading edge and trailing edge. In the case of the pulse output from a simple differentiating circuit, the pulse width is 0.707 of the time constant, as shown in Fig. 117. In other words, at the end of 0.707 of one time constant, the pulse has fallen to 50 percent of maximum amplitude. At the end of one time constant, the pulse has fallen to 37 percent of maximum amplitude. These relations are true of all simple differentiating circuits, regardless of the R and C values.



(A) Differentiating circuit.



(B) Chart.

Fig. 117. The pulse width is 0.707 of the time constant.

RC-COUPLED AMPLIFIERS

U64

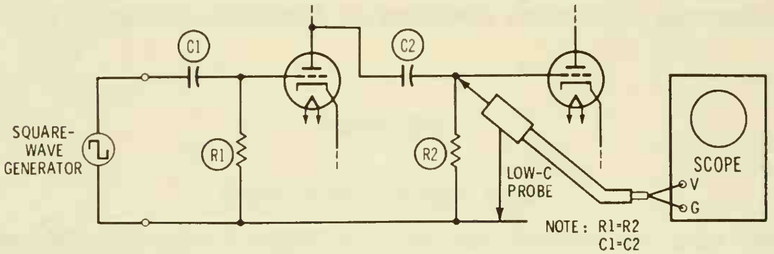
To Check the Low-Frequency Square-Wave Response of a Two-Stage RC-Coupled Amplifier

Equipment: Square-wave generator, triggered-sweep scope with calibrated time bases, and amplifier to be tested.

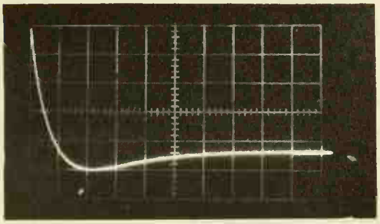
Connections Required: Connect the equipment as shown in Fig. 118A.

Procedure: Set the generator for a low repetition rate and observe the pattern on the scope screen.

Evaluation of Results: The normal response is shown in Fig. 118B. A universal RC time-constant chart for the low-frequency response of a two-stage RC-coupled amplifier is shown in Fig. 119. Note that the chart is based on a two-stage amplifier in which both coupling capacitors have the same value and both grid-return resistances have the same value. The curve in Fig. 119 is not a simple exponential waveform because the first RC circuit changes the square wave into an exponential waveform; this exponential waveform drives the second RC circuit.



(A) Test setup.



(B) Low-frequency square-wave response.

Fig. 118. Low-frequency square-wave response of a two-stage RC-coupled amplifier.

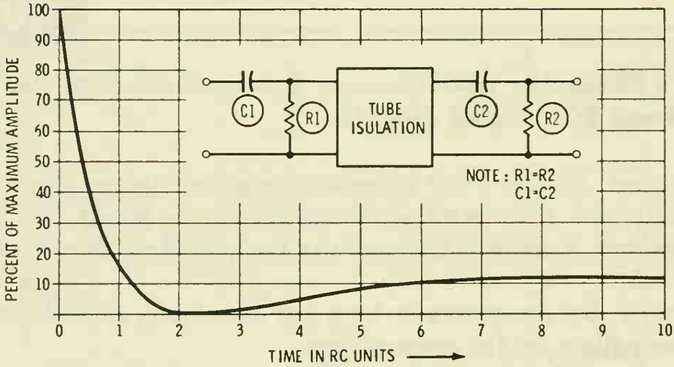


Fig. 119. A universal RC time-constant chart for a two-stage RC-coupled amplifier; low-frequency square-wave response.

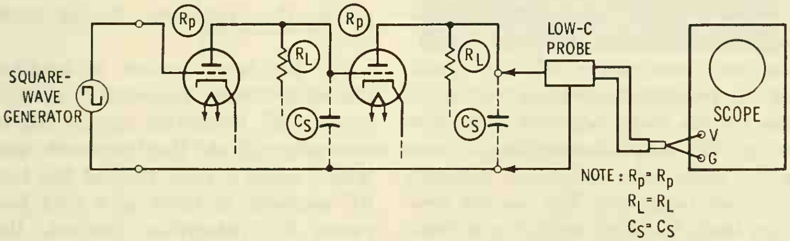
To Check the High-Frequency Square-Wave Response of a Two-Stage RC-Coupled Amplifier

Equipment: Square-wave generator, scope, and amplifier to be tested.

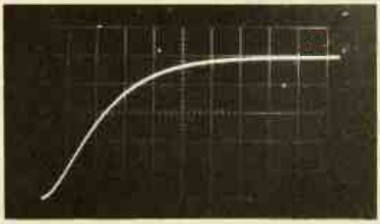
Connections Required: Connect the equipment as shown in Fig. 120A.

Procedure: Apply a high-frequency square-wave signal to the amplifier. Speed up the deflection rate of the scope to expand the leading edge of the output waveform, as seen in Fig. 120B.

Evaluation of Results: Each of the tubes has a plate resistance R_p. This plate resistance combines in parallel with the load resistance, R_L. In turn, the resultant resistance feeds into the stray capacitance, C_s. Accordingly, each stage is an equivalent integrating circuit. The rise time of the output waveform depends on the time constant in each stage; the photo shows the normal output waveform for equal time constants. The output waveform is not a simple exponential because the first stage changes the square wave into a simple exponential waveform, and this exponential waveform in turn drives the second stage. Therefore, the output waveform is the product of two exponential waveforms. A universal RC



(A) Test setup.



(B) High-frequency square-wave response.

Fig. 120. High-frequency square-wave response of a two-stage RC-coupled amplifier.

time-constant chart for a two-section integrator with tube isolation between sections is shown in Fig. 121.

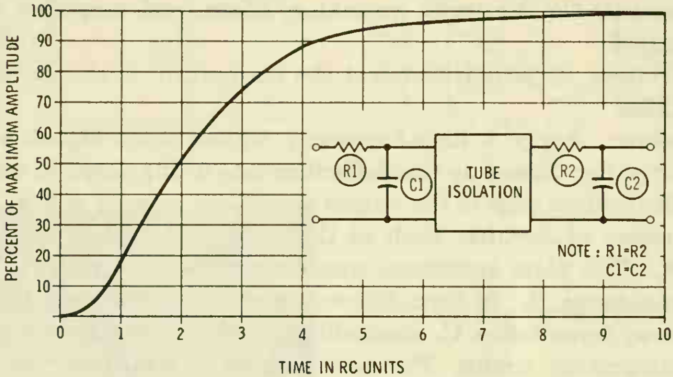


Fig. 121. Universal RC time-constant chart for a two-stage RC-coupled amplifier; high-frequency square-wave response.

NOTE 35

Effect of Isolation on Waveforms in RC Circuits

You will have observed that the square-wave response of a two-section symmetrical RC differentiating circuit is somewhat similar to the square-wave response of a two-stage RC-coupled amplifier. However, there is a difference between the two responses. The second section loads the first section in a two-section symmetrical differentiating circuit; on the other hand, tube isolation eliminates loading between RC sections in the two-stage amplifier. In the case of the two-section differentiator, the waveform decays faster because of loading. On the other hand, in the case of the amplifier, the waveform decays more slowly.

For the same reason of loading, the square-wave response of a two-section RC integrator circuit differs somewhat from the response obtained when a tube isolates the two RC sections. If there is a tube between the integrator sections, the output waveform rises faster because of the absence of loading. Therefore, when circuits are connected in cascade, our analysis must consider whether one circuit is loaded by a following circuit, or whether the first circuit may be isolated from the second circuit by a tube and is thereby unloaded.

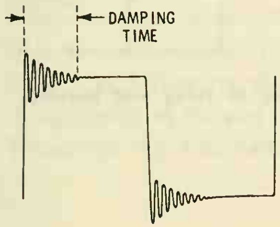
To Measure the Damping Time of a Ringing Waveform

Equipment: Square-wave generator, triggered-sweep scope, and amplifier to be tested.

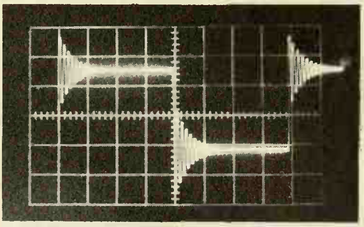
Connections Required: Connect the equipment for a conventional square-wave test; for example, see U64 or U65.

Procedure: Expand the reproduced square wave as required to make the ringing interval occupy one or two centimeters horizontally, as illustrated in Fig. 122B.

Evaluation of Results: The damping time is defined as the elapsed time from the start of the ringing interval to the point at which the top of the square wave "settles down," as depicted in Fig. 122A. In Fig. 122B, the damping time occupies approximately two centimeters. Note the cm/sec setting of the time-base controls to measure the damping time. In an RC-coupled amplifier, ringing usually results from leakage inductance in the output transformer.



(A) Definition of damping time.



(B) Damping time is measured by calibrated sweeps.

Fig. 122. Damping time of a ringing waveform.

U67

To Check the Square-Wave Response of an Amplifier with a Mercury Switch

Equipment: Mercury relay, flashlight battery, audio oscillator, coaxial cable, terminating resistor, oscilloscope, and amplifier to be tested.

Connections Required: Connect the square-wave generating circuit as shown in Fig. 123. Connect the oscilloscope across the load resistor at the output terminals of the amplifier.

Procedure: Advance the output from the audio oscillator, as required, to operate the mercury relay. Set the audio oscillator to any frequency up to 200 cps (or higher, if the relay will respond to higher frequencies).

Evaluation of Results: The square-wave response of the amplifier is evaluated in the same manner as for a conventional square-wave generator. A mercury relay has the advantage that the square wave has a perfectly flat top at any frequency and a much faster rise than square-wave generators using tubes or transistors. In turn, the harmonics are stronger, and more detail may be visible in the reproduced square wave, provided the scope has adequate response.

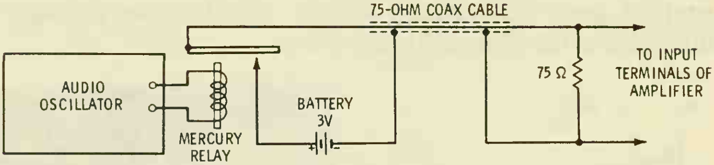
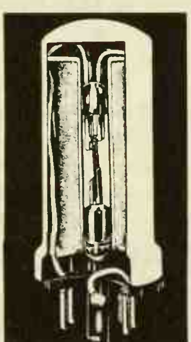


Fig. 123. Connection of output cable to relay and battery.

NOTE 36

Mercury Relay Must Be Operated Vertically

A mercury relay (see Fig. 124) must be operated in a vertical position. Otherwise, the mercury will not feed properly through the capillary grooves to the contacts. Note also that the contacts have limited current capability; therefore, the output leads should not be short-circuited. To avoid ringing in the generated waveform, keep the leads from the battery very short and terminate the coax cable in its characteristic resistance. Use a composition resistor for termination; a wirewound resistor will ring excessively.



Courtesy Potter and Brumfield, Div. AMF Co.

Fig. 124. Cutaway view of a mercury relay.

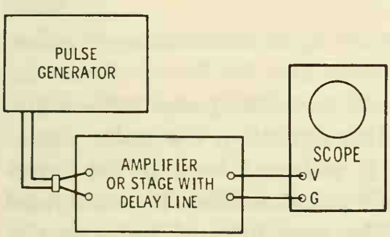
To Check a Delay Line in an Amplifier

Equipment: Pulse generator with faster rise time than the amplifier under test, and a scope with a faster rise time than the amplifier.

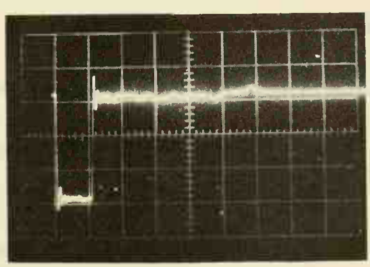
Connections Required: Connect the equipment as shown in Fig. 125A.

Procedure: Keep the output from the pulse generator below the amplifier overload point, as evidenced by artificial flat-topping of the output pulse. Use sufficient pulse width for a convenient display. Pulse repetition rate is arbitrary—higher repetition rates provide a brighter pattern.

Evaluation of Results: If the delay line in the amplifier is properly terminated, a pulse waveform is reproduced with minimum distortion, as seen in Fig. 125B. An overshoot of less than 10 percent, followed by ringing, will be observed in conventional delay lines. Only the elaborate delay lines used in lab-type scopes have little or no overshoot and ringing. Thus, delay lines used in video amplifiers normally develop noticeable overshoot and ringing. Observe the somewhat irregular base line following the reproduced pulse in Fig. 125B. This irregularity is caused by internal reflections in the delay line. When the input impedance and the output impedance (source



(A) Test setup.



(B) Waveform.

(C) External modulator.

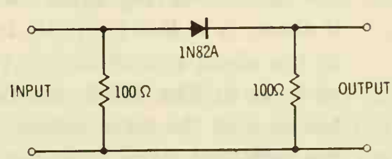


Fig. 125. Output for a normally operating delay line.

and load impedances) match the characteristic impedance of the delay line, internal reflections are minimized. Nevertheless, ordinary delay lines have noticeable residual internal reflections because they are fabricated from lumped values of L and C. To obtain a completely smooth base line, a very large number of inductors and capacitors or some form of true transmission line must be used.

U69

To Check for Open-Circuit or Short-Circuit Delay-Line Termination

Equipment: Pulse generator, composition resistor with a value equal to the characteristic impedance of the delay line, and scope.

Connections Required: Connect the equipment as shown in Fig. 126.

Procedures: Apply a pulse of convenient width and repetition rate; observe the pattern on scope screen. The dotted lines and short circuit depicted at the output end of the delay line in Fig. 126 indicate a possible open circuit or short circuit in the delay line.

Evaluation of Results: If there is an open connection or other cause of an open circuit in the delay line, the line is effectively terminated in an open circuit. In turn, the pattern displayed is as shown in Fig. 127A. In this situation, the pulse signal stops at the open circuit and is reflected back to the input end of the delay line in the same polarity. The reflected pulse becomes distorted as shown. The time interval between the applied pulse and the reflected pulse indicates how far down the delay line the open circuit occurs. On the other hand, if there is a short circuit in the delay line, the pulse stops at the short circuit and is reflected in the opposite polarity, as seen in Fig. 127B. As before, the reflected pulse is distorted and the time interval between the applied pulse and the reflected pulse indicates how far down the delay line the short circuit occurs.

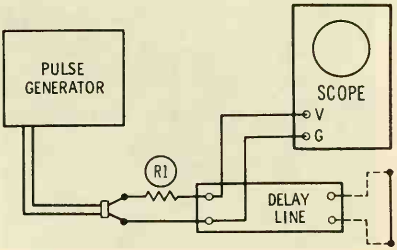
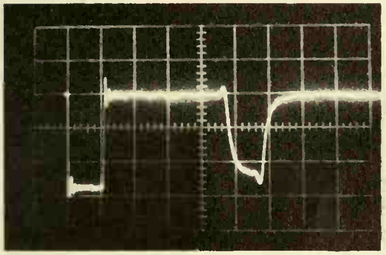
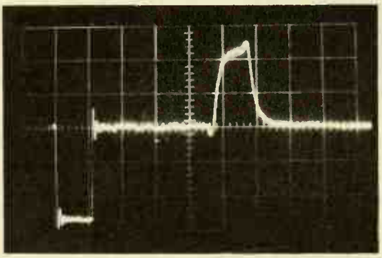


Fig. 126. Test setup for checking delay-line termination.



(A) Open-circuited.



(B) Short-circuited.

Fig. 127. Waveforms of a delay line.

U70

To Measure the Delay Time of a Normally Operating Delay Line

Equipment: The same as in U69, except that a scope with calibrated time base is required.

Connections Required: The same as in U69. The output end of the delay line may be left open or the output terminals may be short-circuited.

Procedure: The same as in U69.

Evaluation of Results: Waveforms such as those illustrated in Fig. 127 will be displayed. Measure the elapsed time from the leading edge of the applied pulse to the leading edge of the reflected pulse. One-half of this elapsed time is equal to the

delay time of the line. In other words, the applied pulse must first travel to the output end of the delay line and then must travel back to the input end of the line. Thus, the measured elapsed time is equal to twice the delay time.

U71

To Check the Characteristic Impedance of a Delay Line

Equipment: Pulse generator, assortment of composition resistors, and a scope.

Connections Required: Connect the equipment as shown in Fig. 128; the output end of the delay line is left open-circuited (no resistive termination used).

Procedure: Apply a pulse of convenient width and repetition rate. Observe the base line following the reproduced pulse.

Evaluation of Results: If the value of R in Fig. 128 is not equal to the characteristic impedance of the delay line, a reflected pulse appears as seen in Fig. 129A. Accordingly, change the value of R as required to eliminate the reflected pulse. Fig. 129B shows the screen pattern obtained when the value of R is almost equal to the characteristic impedance of the delay line. A precise measurement requires that the output impedance of the pulse generator be added to the value of R that is determined in the foregoing test. For example, if the output impedance of the generator is 75 ohms and the value of R for best match is found to be 350 ohms, then the actual characteristic impedance of the delay line is 425 ohms.

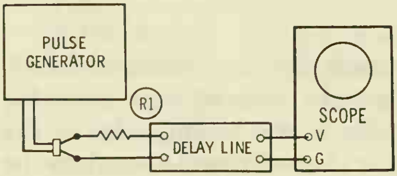
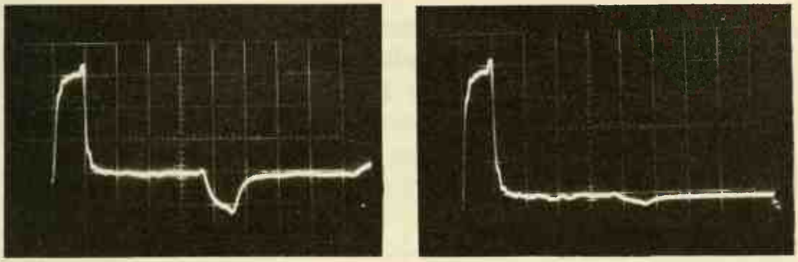


Fig. 128. Test setup for checking characteristic impedance of a delay line.



(A) R not equal to Z_0. (B) R nearly equal to Z_0.

Fig. 129. Waveforms of delay-line characteristic impedance.

U72

To Check a Delay Line for Preshoot

Equipment: Pulse generator with faster rise than the delay line under test, source and load matching resistors, and a scope with a faster rise than the delay line.

Connections Required: Connect the equipment as shown in Fig. 130.

Procedure: Use the external trigger function of the scope; this permits the pattern to be displayed at the center of the screen, as shown in Fig. 131. Apply a pulse signal of any convenient width and repetition rate.

Evaluation of Results: The base line leading up to the reproduced pulse is displayed when the external-trigger function of the scope is used. In turn, any preshoot that occurs is apparent.

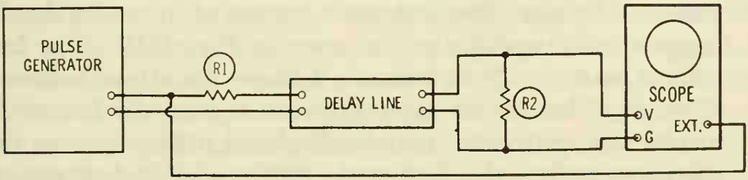


Fig. 130. Test setup for checking delay-line preshoot.

In Fig. 131, we observe a small dip prior to the leading edge of the displayed pulse; this dip is the preshoot introduced by the delay line. Some delay lines have more preshoot than others. Certain designs eliminate preshoot, although the rise time may be less. The design of any delay line is a compromise between fast rise and residual pulse distortion.

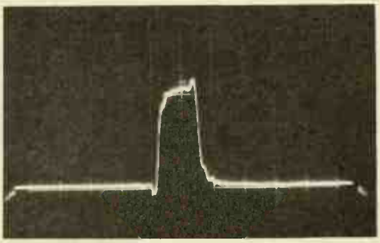


Fig. 131. Delay-line output with delayed trigger.

U73

To Make a Tone-Burst Test of an RC Amplifier

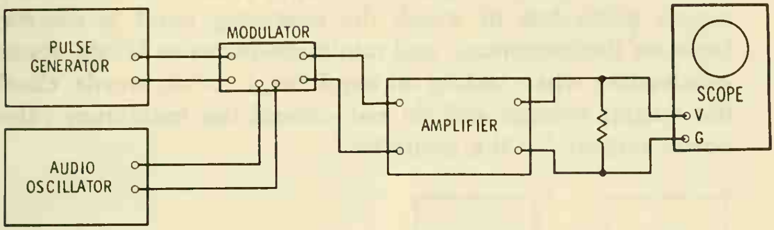
Equipment: Pulse generator, modulator, audio oscillator, terminating resistor for amplifier, and oscilloscope.

Connections Required: Connect the equipment as shown in Fig. 132A.

Procedure: Adjust the generator outputs below the point of overloading (evidenced by clipping of the tone burst). Set the pulse width to include several cycles of the tone signal. Adjust the repetition rate to provide substantial separation between successive tone bursts. Observe the screen pattern at tone-burst frequencies of 400 cps and a low frequency such as 100 cps, and again at a high frequency such as 10 kc.

Evaluation of Results: The sine-wave pattern of the burst should be essentially undistorted, as seen in Fig. 132B. The first cycle is most significant because it shows the attack response of the amplifier. If the attack response is poor, the first cycle will be attenuated or it may be displaced with respect to the following cycles; the first cycle might also undershoot or overshoot. In some cases, the last cycle is distorted when the

sine-wave signal abruptly ceases. Adjustment of the amplifier tone controls will affect the attack characteristic.



(A) Test setup.

(B) Tone-burst waveform.

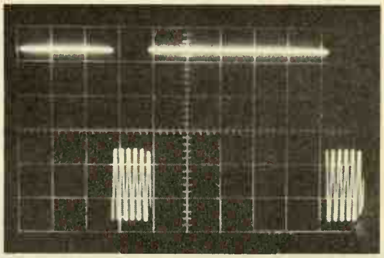


Fig. 132. Tone-burst test of an RC amplifier.

U74

To Generate a Serrated Signal for Amplifier Tests

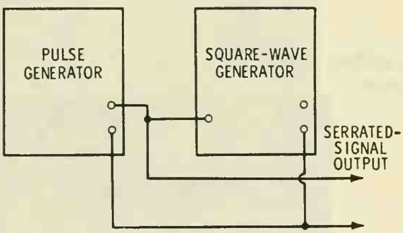
Equipment: Pulse generator and square-wave generator; square-wave generator must provide for external synchronization.

Connections Required: Connect the equipment as shown in Fig. 133A.

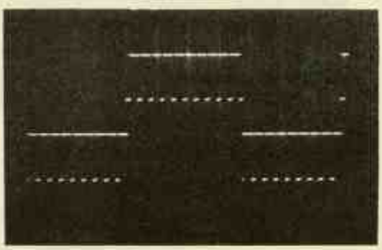
Procedure: Adjust the pulse generator for the desired serration width and repetition rate; adjust the square-wave generator for the desired repetition rate. Set the sync-amplitude control of the square-wave generator for a stable pattern. Set the output-amplitude controls of the generators as required.

Evaluation of Results: RC-coupled amplifier tests with the serrated-pulse signal are informative because the pulse response

can be observed with operating points near the maximum- and minimum-response levels of the amplifier. In turn, the test is more demanding than a simple square-wave test or a simple pulse test in which the operating point is midway between the maximum- and minimum-response levels. Avoid overloading when testing an amplifier; in other words, check the output voltage and do not exceed the maximum rated power output for the amplifier.



(A) Test setup.



(B) Serrated-signal waveform.

Fig. 133. A serrated signal for an amplifier test.

MISCELLANEOUS TESTS

U75

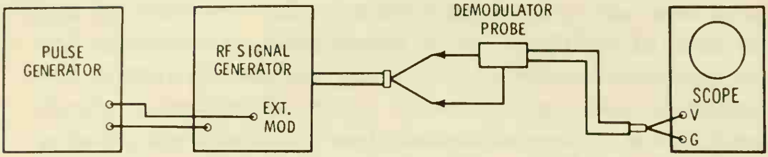
To Check the Pulse Response of a Demodulator Probe

Equipment: Pulse generator, RF signal generator with external-modulation facility, demodulator probe, and scope.

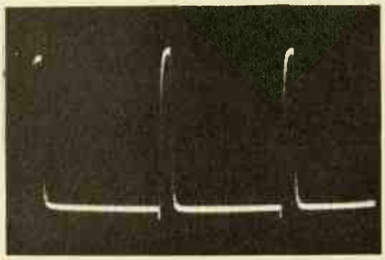
Connections Required: Connect the equipment as shown in Fig. 134A.

Procedure: Set the RF signal generator to a frequency such as 30 Mc; adjust the pulse-generator output for full modulation of the RF generator; reduce the pulse width while observing the pattern on the scope screen. Any convenient pulse repetition rate may be used.

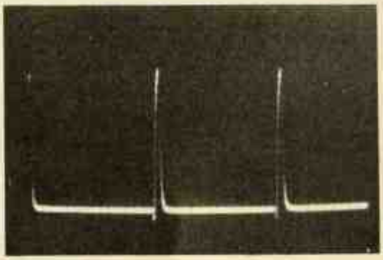
Evaluation of Results: The better the demodulator probe, the narrower the pulse width that can be displayed at normal amplitude. In the example shown in Fig. 134B, a pulse width of 100 μs is displayed at normal amplitude with noticeable corner rounding. However, as seen in Fig. 134C, the pulse becomes "feathered" and starts to fall in amplitude at a pulse width of 50 μs.



(A) Test setup.



(B) 100-microsecond pulse width.



(C) 50-microsecond pulse width.

Fig. 134. Pulse response of a demodulator probe.

U76

To Check the Square-Wave Response of a Demodulator Probe

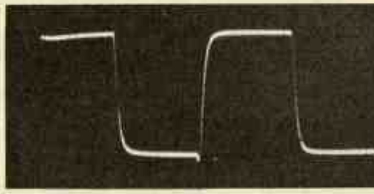
Equipment: Same as in U75, except that a square-wave generator is used instead of a pulse generator.

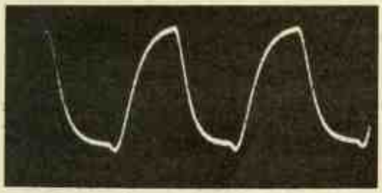
Connections Required: Same as in U75.

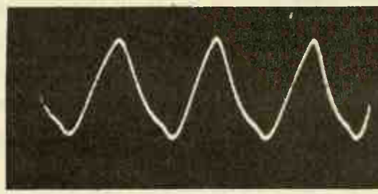
Procedure: Increase the repetition rate of the square-wave generator while observing the pattern displayed on the scope screen.

Evaluation of Results: At some upper repetition rate, the reproduced square wave will become objectionably distorted. Fig. 135 shows the square-wave response of a typical demodulator probe at 2, 10, and 20 kc. A typical demodulator probe and specifications are shown in Fig. 136.

(A) 2-kc response.

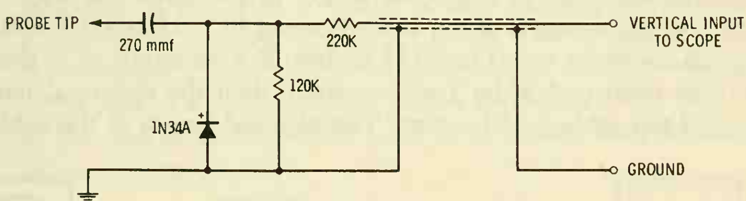






(B) 10-kc response. (C) 20-kc response.

Fig. 135. Square-wave response of a demodulator probe.



(A) Test setup.

FREQUENCY RESPONSE CHARACTERISTICS:	
RF CARRIER RANGE	500 KC to 250 MC
MODULATED-SIGNAL RANGE	30 to 5000 CYCLES
INPUT CAPACITANCE (APPROX.)	2.25 mmf
EQUIVALENT INPUT RESISTANCE (APPROX.):	
AT 500 KC	25,000 OHMS
1 MC	23,000 OHMS
5 MC	21,000 OHMS
10 MC	18,000 OHMS
50 MC	10,000 OHMS
100 MC	5000 OHMS
150 MC	4500 OHMS
200 MC	2500 OHMS
MAXIMUM INPUT:	
AC VOLTAGE	20 RMS VOLTS 28 PEAK VOLTS

(B) Specifications.

Fig. 136. Typical demodulator probe and specifications.

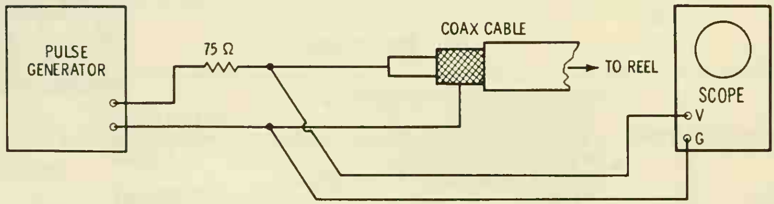
To Measure the Length of Coaxial Cable on a Reel

Equipment: Pulse generator, 75-ohm composition resistor, and scope with calibrated time base.

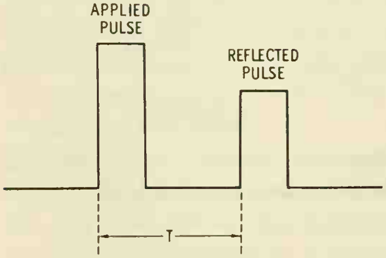
Connections Required: Connect the equipment as shown in Fig. 137A.

Procedure: Adjust the pulse generator for a sufficiently narrow pulse width so that the applied pulse and reflected pulse are separated on the scope screen and do not overlap. The shorter the length of cable on the reel, the narrower is the pulse that is desirable for ease of measurement. The repetition rate is arbitrary; higher repetition rates provide a brighter pattern.

Evaluation of Results: With reference to Fig. 137B, measure the elapsed time T from the leading edge of the applied pulse to the leading edge of the reflected pulse. This is double the total travel time; hence, one-half of T is the time required for the pulse to travel the length of the cable one way. The *electrical* length of the cable is equal to 150,000,000 T meters. A meter is equal to 39.37 inches. For example, if T should be measured to be 1 microsecond, then the electrical length of the cable is 150 meters. The *physical* length of the cable is



(A) Test setup.



(B) Measurement of travel time.

Fig. 137. Measuring the length of a coaxial cable on a reel.

equal to 0.66 times its electrical length, because a pulse travels slower in a coax than in an ideal cable. Hence, to continue the foregoing example, the physical length of the coax cable would be 99 meters, or about 325 feet.

U78

To Measure the Distance to a Fault on a Cable or Line

Equipment: Same as in U77.
Connections Required: Same as in U77.
Procedure: Same as in U77.
Evaluation of Results: A fault on a cable or a line may consist of an open circuit, a short circuit, or a shunt-leakage path due to insulation breakdown. The fault pattern will be the same as depicted in Fig. 137B if the fault is due to an open circuit. However, if the fault is due to a short circuit, the reflected pulse will be inverted in polarity. In the case of coaxial cable, the distance to the fault is calculated as in U77B. However, in the case of a twin-lead line, we use a velocity factor of 0.82; in the case of air dielectric, such as in *Gonset* line, we use a velocity factor of 0.975.

U79

To Check the Performance of a Flip-Flop

Equipment: Pulse generator with a faster rise time than the flip-flop circuit under test, and a scope with a faster rise time than the flip-flop circuit. A calibrated time base is desirable.
Connections Required: With reference to Fig. 138, pulses of positive polarity (in this example) are used to trigger the flip-flop; the scope is connected at the output of the flip-flop.
Procedure: Advance the output from the pulse generator to obtain an output from the flip-flop. The pulse width may be quite narrow in typical cases; the repetition rate should be sufficiently low so that normal operation is obtained.

Evaluation of Results: The minimum trigger voltage required occurs at the point where further reduction of pulse amplitude causes no output or erratic output from the flip-flop. With ample trigger voltage the minimum width of trigger pulse occurs at the point where further reduction in pulse width causes no output or erratic output from the flip-flop. In normal operation, one output pulse is obtained for two trigger pulses. That is, the output repetition rate should be one-half of the trigger repetition rate. The width of the output pulse depends on the trigger repetition rate. At some upper limit of trigger repetition rate, erratic operation or no output will be obtained; this is the maximum-response capability of the flip-flop.

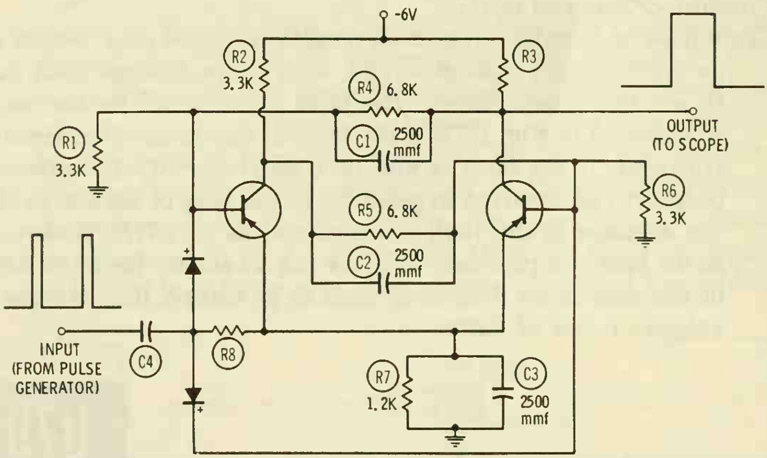


Fig. 138. Flip-flop configuration with a trigger circuit.

U80

To Check the Performance of a One-Shot Multivibrator

Equipment: Same as in U79.

Connections Required: Apply the output from the pulse generator to the trigger input of the one-shot multivibrator (Fig. 139). Connect the scope to the output of the multivibrator.

Procedure: Adjust the output from the pulse generator sufficiently to obtain normal operation of the multivibrator.

Evaluation of Results: The minimum trigger voltage occurs at the point where further reduction in pulse amplitude results in no output or erratic output from the multivibrator. With ample trigger voltage, the minimum width of the trigger pulse occurs at the point where further reduction in pulse width produces no output or erratic output. In normal operation, one output pulse is obtained for each trigger pulse. The width of the output pulse is normally determined only by the circuit parameters, and is independent of the trigger-pulse width or amplitude. At some upper limit of trigger repetition rate, erratic output or no output will occur; this is the maximum-response capability of the one-shot multivibrator.

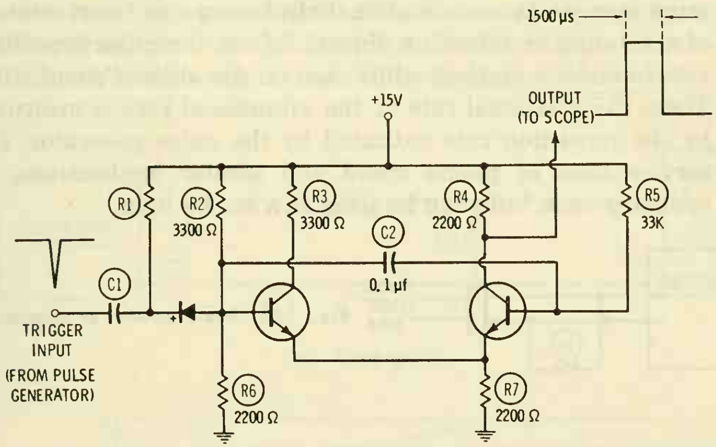


Fig. 139. A typical one-shot emitter-coupled multivibrator.

U81

U81

To Use a Pulse Generator as a Stroboscope

Equipment: Pulse generator and strobe light bulb.

Connections Required: Connect the strobe bulb to the output of the pulse generator (Fig. 140). A shunt resistor may be re-

quired if the generator has a series blocking capacitor in the output; otherwise, omit the resistor.

Procedure: Advance the output from the pulse generator to see if the strobe light can be energized. Some pulse generators have insufficient output voltage. In such a case, an amplifier must be used to boost the pulse voltage. If the strobe light glows, but becomes progressively dimmer and then extinguishes, there is a blocking capacitor present in the generator output circuit. Hence, shunt a suitable value of resistance across the bulb to eliminate back-bias from glow-tube rectification. A value of 10,000 ohms can be tried to start; if the blocking capacitor is quite large, a lower value of resistance may be necessary.

Evaluation of Results: The strobe arrangement is used in the same manner as a conventional stroboscope to "stop motion" of a rotating or vibrating object. Adjust the pulse repetition rate to make a marked white spot on the object "stand still." Then, the rotational rate or the vibrational rate is measured by the repetition rate indicated by the pulse generator. For service tests of phono speed and similar applications, an ordinary neon bulb can be used as a strobe light.

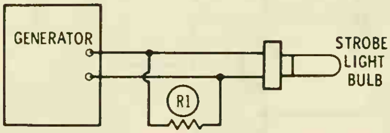


Fig. 140. Basic strobe arrangement.

U82

To Measure the Inductance Value of an Inductor

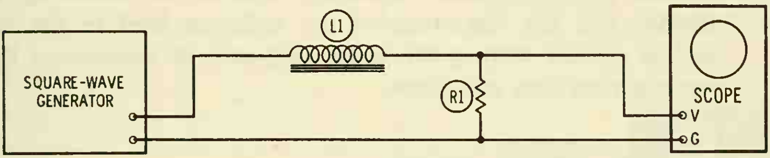
Equipment: Square-wave generator, resistor, and scope with calibrated time base.

Connections Required: Connect the equipment as shown in Fig. 141A.

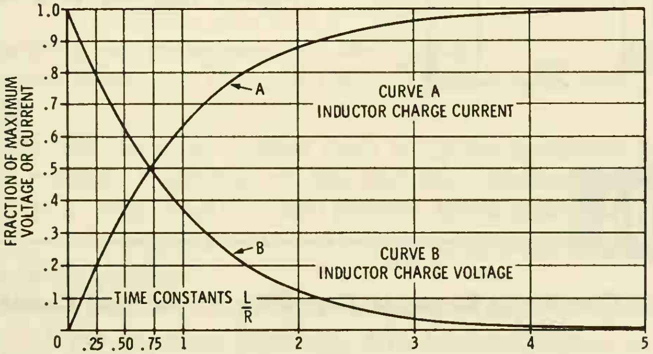
Procedure: Adjust the repetition rate of the square-wave generator to a low value, and note the maximum amplitude of the output waveform on the scope screen. Then, increase the

repetition rate somewhat for convenience of measuring the rise time of the output waveform.

Evaluation of Results: Since the time constant of the circuit is equal to L/R, the inductance in henrys is equal to the resistance in ohms multiplied by the time of rise from zero to the 63 percent-of-maximum-amplitude point. For example, suppose that R equals 100 ohms, and the time of rise to the 63-percent point is 10 milliseconds. Then, L/R is equal to 0.01, and L equals 100 × 0.01 equals 1 henry. Note carefully that the winding resistance of a large inductor is usually significant; therefore, the winding resistance must be measured with an ohmmeter and added to the value of R, depicted in Fig. 141A. The output resistance of the square-wave generator should also be added to the sum of the winding resistance and R. This test is chiefly applicable to low-Q inductors; high-Q inductors will ring and the scope pattern is then objectionably distorted.



(A) Test setup.



(B) Universal time-constant chart.

Fig. 141. Measuring the inductance of an inductor.

To Measure the Pulse-Response Capability of a Transistor

Equipment: Pulse generator and scope, both having faster rise than the transistor under test, with components depicted in Fig. 142.

Connections Required: Connect the test circuit as shown in Fig. 142.

Procedure: Apply sufficient pulse width to obtain a good output-pulse waveshape. Then, decrease the pulse width while observing the screen pattern. The repetition rate is arbitrary. Use a negative pulse to test a PNP transistor.

Evaluation of Results: The maximum pulse-response capability of the transistor occurs at the point where further reduction in pulse width causes an output-pulse waveshape that is distorted and reduced in amplitude. Transistors suitable for use in audio amplifiers have a comparatively limited pulse-response capability; however, transistors suitable for use in video amplifiers have a much faster rise, and in turn, a much greater pulse-response capability. Use of the speed-up capacitor and the low value of the collector load in the test circuit permit testing the pulse response of transistors that have a very fast rise time.

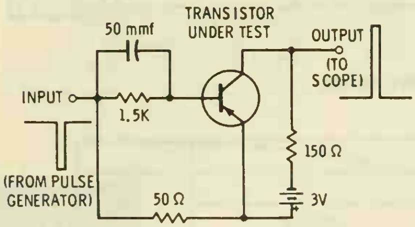


Fig. 142. Test setup for pulse-response capability of a transistor.

U84

To Check the Response Capability of an Eput Counter

Equipment: Pulse generator with a higher repetition rate than the Eput counter under test, and a fast-action switch such as a microswitch.

Connections Required: Connect the output from the pulse generator to the input terminals of the Eput counter via the switch, as shown in Fig. 143.

Procedure: Adjust the pulse generator for minimum pulse width consistent with reliable counter operation. Then, increase the repetition rate while observing the counter response.

Evaluation of Results: An Eput counter or event counter normally reads the number of pulses that have occurred over an elapsed time. For example, if the pulse generator supplies 1000 pulses per second, the counter will normally read 60,000 at the end of one minute. For precise checking, it is desirable to use a stopwatch for measurement of elapsed time. At some upper limit in repetition rate, the counter will respond erratically, or stop completely. This is the maximum-response capability of the counter.

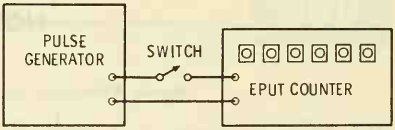


Fig. 143. Test setup to check the response capability of an Eput counter.

U85

To Check the Response Capability of a Staircase Generator

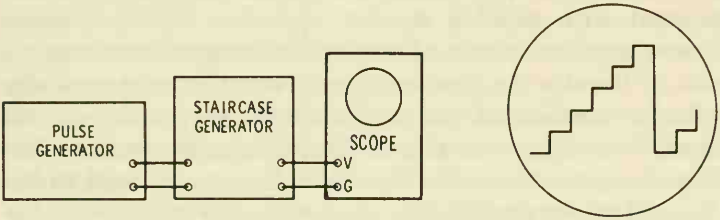
Equipment: Pulse generator and oscilloscope.

Connections Required: Connect the equipment as shown in Fig. 144A.

Procedure: Advance the output from the pulse generator to obtain normal triggering of the staircase generator. Use as narrow a pulse width as will provide stable operation. Then, increase the repetition rate of the pulse generator, observing the scope patterns.

Evaluation of Results: At an upper limiting repetition rate, operation of the staircase generator will become erratic, or will stop completely. This is the maximum-response capability of the staircase generator. Note that a staircase signal is commonly employed to display families of collector characteristics

for transistors on a scope screen. Similarly, a staircase signal can be used to display the plate family of characteristics for a vacuum tube.



(A) Test setup. (B) Screen pattern.

Fig. 144. Response capability of a staircase generator.

NOTE 37

Basic Principle of Staircase Generator

The basic principle of a staircase generator is shown in Fig. 145. On the positive half-cycle of square-wave output, C1 charges to the peak voltage of the signal. Next, on the negative half-cycle of square-wave output, C2 charges in series with C1. If C1 has a much smaller capacitance than C2, many "step" charges must flow into C2 before its voltage rises high enough to fire the neon bulb. For example, C1 might have a value of 0.01 mfd, and C2 a value of 0.5 mfd. The staircase signal appears across the neon bulb, which operates as a reset switch. The amplitude of the staircase signal is the difference between the ionization voltage and the extinction voltage of the neon bulb.

Note that the square-wave generator must provide sufficient output voltage to ionize the neon bulb; not all square-wave generators have sufficient output. If the capacitors are leaky, the staircase signal will be distorted, or the circuit will refuse to operate. Hum voltage can be troublesome and cause distortion because of the high-impedance circuitry. It may be desirable in some cases to power the diode heaters from a DC supply, and to place the components in a grounded metal box. Make certain that the diodes are free from heater-cathode leakage. This is a basic configuration, and the staircase signal is not quite linear because of the curved charging characteristic of C2. However, if the output is passed through an amplifier, biased to introduce an opposite curvature, the staircase signal can be completely linearized.

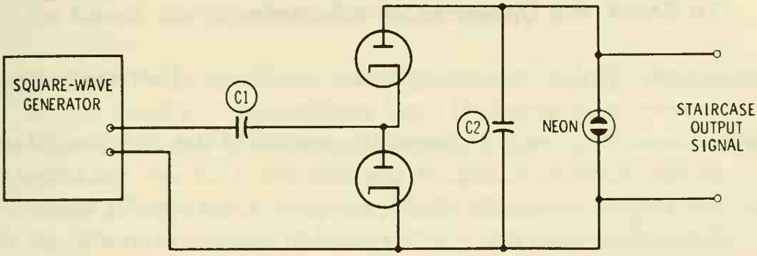


Fig. 145. An elementary staircase generator.

U86

To Check a Pulse Counter

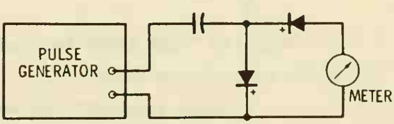
Equipment: Calibrated pulse generator.

Connections Required: Connect the pulse generator to the pulse counter as depicted in Fig. 146.

Procedure: Set the pulse output to the reference level. Vary the repetition rate and the pulse width, observing the meter indication.

Evaluation of Results: The meter reading should agree with the repetition-rate setting of the pulse generator, within experimental error. At some lower limit of pulse width, the meter indication will start to decrease; this is the narrowest pulse width that can be properly processed by the pulse counter. Note that the output voltage from the pulse generator must be set to a reference level in Fig. 146 because no limiter is included between the generator and the counter circuit. If a limiter is provided, any pulse amplitude in excess of the limiting level may be applied, and the meter reading will remain unchanged.

Fig. 146. A basic pulse counter.



To Check the Operation of a Sampler

Equipment: Pulse generator, audio oscillator (or other signal source to be sampled), and oscilloscope.

Connections Required: Connect the output of the audio oscillator to the input terminals of the sampler. Connect the scope to the output terminals of the sampler. Connect the output of the pulse generator to the enabling-gate terminals of the sampler as shown in Fig. 147.

Procedure: Set the generator outputs sufficiently high to obtain a scope pattern. Adjust the pulse generator for a repetition rate to obtain the desired number of samples in each cycle of the sine wave. Vary the pulse width while observing the scope pattern.

Evaluation of Results: At some lower limit of pulse width, operation will become erratic or stop completely. This test determines the pulse-width capability of the sampler. As the audio-oscillator frequency is increased, the pulse repetition rate must also be increased to maintain the same number of samples per cycle. At some upper frequency limit, sampling action will become unstable. This is the maximum-frequency capability of the sampler.

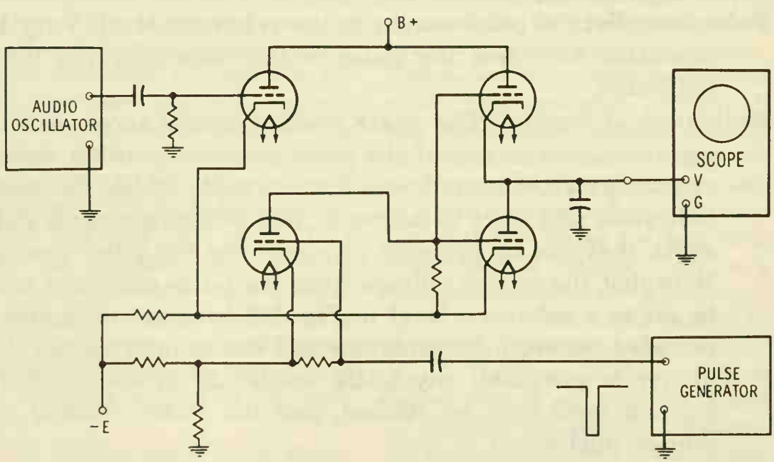


Fig. 147. Test setup to check the operation of a sampler.

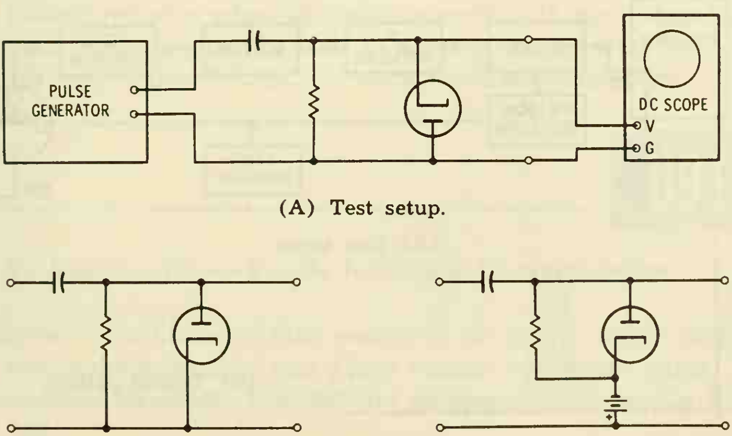
To Check the Operation of a Clamper

Equipment: Pulse generator and DC scope. (An AC scope cannot be used.)

Connections Required: Connect the equipment as shown in Fig. 148A.

Procedure: Vary the output amplitude, pulse width, and pulse repetition rate while observing the pulse waveform displayed on the scope screen.

Evaluation of Results: The arrangement in Fig. 148A is a positive clamping circuit with a reference level of zero volts. In other words, the pulse waveform normally rests on the zero-volt level and is deflected upwards on the scope screen, regardless of the pulse amplitude, width, or repetition rate. If the displayed waveform is not locked to the zero-volt level, the trouble is most likely due to capacitor leakage or to heater-cathode leakage in the diode. Depending on the rise time of the test pulse, there is a minimum pulse width that can be locked to the base line; narrower pulses will fall more or less below the base line. The clamper shown in Fig. 148B is a negative clamping circuit with a reference level of zero volts. The displayed waveform normally rests on the zero-volt level and is deflected downward on the scope screen. Again, Fig. 148C depicts a negative-reference clamper; the displayed



(A) Test setup.

(B) Negative clamper. (C) Negative-reference clamper.

Fig. 148. Checking a positive clamping circuit.

waveform normally rests at a negative level of E volts, and is deflected downward on the scope screen.

U89

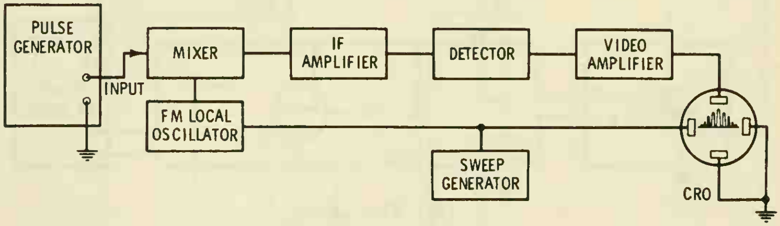
To Check the Operation of a Spectrum Analyzer

Equipment: Pulse generator.

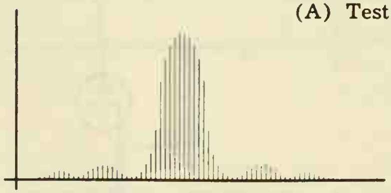
Connections Required: Connect the equipment as shown in Fig. 149A.

Procedure: Vary the pulse width while observing the displayed pattern. The repetition rate is arbitrary, although the null points in the pattern will shift.

Evaluation of Results: As the pulse width is reduced, the harmonics increase in amplitude. The highest point in the center of the pattern is the fundamental frequency of the pulse. As the repetition rate is increased, the nulls move in closer to the carrier. Both even and odd harmonics are always present in the pattern unless the repetition rate is such that a square wave is being applied instead of a pulse waveform.



(A) Test setup.



(B) Typical pattern.

Fig. 149. Checking a spectrum analyzer.

In such a case, the even harmonics disappear. If the applied pulse waveform has a true rectangular shape, the spectrum display is symmetrical on either side of the fundamental. Most trouble in spectrum analyzers is caused by defective tubes. However, as in any electronic equipment, other components may also become defective.

U90

To Use a Pulse Generator as a Radio-Signal Injector

Equipment: Small capacitor (5 or 10 mmf).

Connections Required: Connect the capacitor in series with the "hot" output lead from the pulse generator.

Procedure: Use the capacitor as a probe and touch it to any signal point in the radio at which it is desired to inject a test signal. Set the pulse generator for approximately a 1-kc repetition rate and a narrow pulse width such as 1 μs. Adjust the generator output level as required.

Evaluation of Results: The repetition rate is at an audio-frequency rate; however, the test signal also has an extensive spectrum of harmonics through the AM radio range. Accordingly, it is a signal source that provides an audible output from a normal receiver when the pulse waveform is injected at any point in the signal channel. In a defective receiver, start at the audio output stage and work back, stage by stage.

U91

To Check a Power Supply for Ripple Characteristics

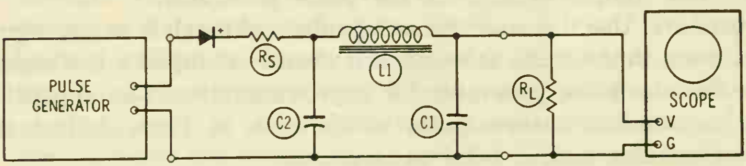
Equipment: Rectifier and filter section of the power supply under test, pulse generator, and a load resistor of suitable value.

Connections Required: Connect the equipment as shown in Fig. 150.

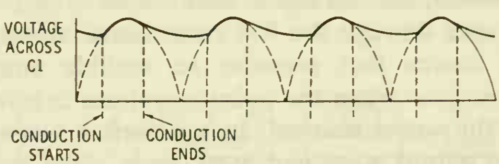
Procedure: Apply a positive-pulse signal at a repetition rate that corresponds to the intended operating frequency (such as

60 cps, 120 cps, 500 cps, etc.). Adjust the pulse width to correspond to the calculated conduction period of the rectifier.

Evaluation of Results: With a chosen value of R_L in Fig. 150, a corresponding ripple amplitude will be displayed on the scope screen. This method is useful in making comparative tests of various types of filters. It is also useful in design work for determining the amount of ripple resulting from various operating frequencies. The effect of increasing filter capacitance can be accurately measured, as well as the effect of various choke inductances. Note that a rectifier is required in the test setup; it is needed to open-circuit the filter input between pulses and thereby establish normal operating conditions. The filter-capacitor charge back-biases the rectifier, and pulse current flows only when the pulse amplitude exceeds the back-bias voltage.



(A) Test setup.



(B) Typical ripple waveform.

Fig. 150. Checking for ripple in a power supply.

U92

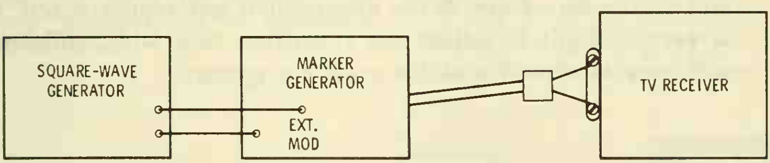
To Check the Deflection Linearity of a TV Receiver

Equipment: Square-wave generator and marker generator with external-modulation facility.

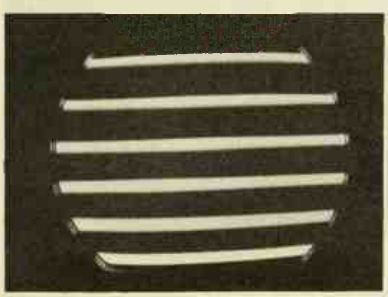
Connections Required: Connect the equipment as shown in Fig. 151A.

Procedure: Tune the marker generator to the picture-carrier frequency of the channel to which the TV receiver is set. Adjust the output from the square-wave generator for suitable modulation of the RF signal. Adjust the frequency of the square-wave generator to display the desired number of vertical or horizontal bars.

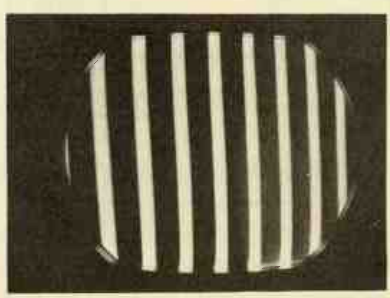
Evaluation of Results: Typical bar patterns are illustrated in Figs. 151B and C. When checking horizontal linearity, it is desirable to adjust the vertical-hold control of the TV receiver to exactly 60 cps. This makes the vertical bars hold still on the screen, free from "snaking." The vertical bars will nevertheless be curved more or less, depending on the residual hum level in the TV receiver. When the frequency of the square-wave generator is reduced to display horizontal bars on the screen, hum is not a problem and no "snaking" is encountered.



(A) Test setup.



(B) Vertical pattern.



(C) Horizontal pattern.

Fig. 151. Checking the deflection linearity of a TV receiver.

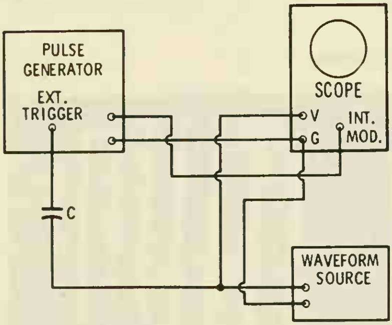
To Use a Pulse Generator as a Time-Mark Generator

Equipment: Scope, small coupling capacitor, and source of waveform to be marked.

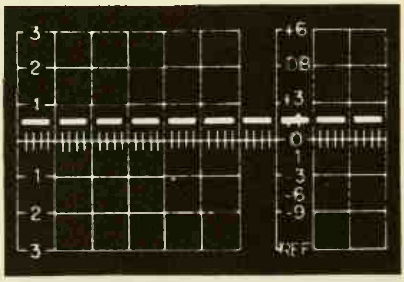
Connections Required: Connect the equipment as shown in Fig. 152A.

Procedure: Use as small a coupling capacitor as will provide stable synchronization of the pulse generator. (A trimmer capacitor is convenient for this purpose.) Set the pulse generator for a pulse width that gives small, but clearly visible, blank spots in the displayed waveform. Adjust the repetition rate of the pulse generator to mark desired time intervals along the waveform.

Evaluation of Results: The time between successive blank spots along the displayed waveform is equal to the reciprocal of the repetition rate to which the pulse generator is set. For example, if the repetition rate is 100 kc, then the time between marking spots is 10 microseconds. Note that the pulse generator must be externally triggered to make the marks stand still on the waveform. If the generator is not synchronized, it is very difficult to adjust the repetition rate with sufficient accuracy to obtain a stable marking pattern.



(A) Setup.



(B) Time marks on a horizontal trace.

Fig. 152. A pulse generator used as a time-mark generator.

To Measure the Pulse Capability of a Capacitive-Divider Probe

Equipment: Pulse generator and scope.

Connections Required: Connect the equipment as shown in Fig. 153.

Procedure: Increase the pulse width gradually while observing the pattern on the scope screen.

Evaluation of Results: At some limiting pulse width, objectionable distortion will be observed in the reproduced pulse. This is the widest pulse that can be processed by the probe, regardless of repetition rate. A capacitance-divider probe integrates wide pulses because a wide pulse contains lower-frequency components than a narrow pulse. Since a capacitance-divider probe is uncompensated, it has limited ability to process low frequencies.

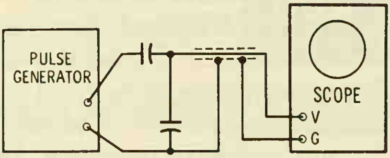


Fig. 153. Setup for measuring the pulse capability of a capacitive-divider probe.

U95

To Check the Transient Response of a Tape Recorder

Equipment: Pulse generator, scope, and load resistor to substitute for the speaker.

Connections Required: Connect the equipment as shown in Fig. 154.

Procedure: Set the pulse generator to a suitable pulse width, such as 50 milliseconds; the repetition rate is arbitrary. Use a low-level pulse output. Record the pulse waveform on the tape and then play it back into the scope.

Evaluation of Results: The pulse waveform should be reproduced without excessive distortion. Rise time of the pulse should be as fast as, or faster than, the rise time of the recorder amplifier when tested separately. If excessive pulse distortion

occurs in the tape, check the recording head for wear. Better pulse reproduction will be obtained at higher speeds of tape travel.

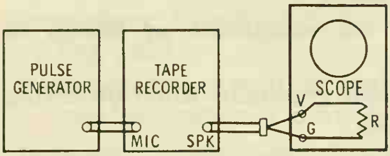


Fig. 154. Checking the transient response of a tape recorder.

U96

To Make a Tone-Burst Test of a Tape Recorder

Equipment: Same as in U72.

Connections Required: Same as in Fig. 154, except that the tone-burst source is used instead of the pulse generator alone.

Procedure: Same as in U72.

Evaluation of Results: The tone burst should be reproduced without excessive distortion., In case of difficulty, check the recording head for wear. As in the case of pulse reproduction, tone-burst reproduction (particularly at high frequencies) is better at higher speeds of tape travel.

U97

To Make a Transient-Response Test of a Speaker

Equipment: Pulse generator, amplifier and speaker to be tested, good-quality microphone, and scope.

Connections Required: Connect the equipment as shown in Fig. 155.

Procedure: Test should be made in a large open area, preferably, to avoid any acoustic reflections. Vary the pulse width from a small to a large value. The repetition rate is arbitrary.

Evaluation of Results: Many speakers have poor transient response, and some distort a pulse so extensively that it is

unrecognizable. Best results are obtained with any speaker if it is critically damped by the amplifier output system. Measurement of critical-damping resistance is explained in U98.

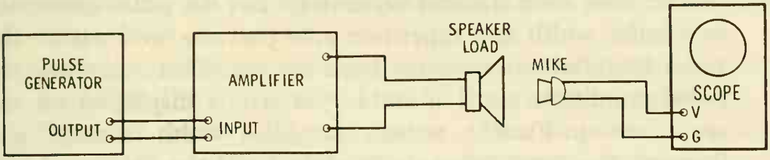


Fig. 155. Testing the transient response of a speaker.

U98

To Measure the Critical-Damping Resistance of a Speaker

Equipment: Pulse generator, scope, crystal diode, 120K resistor, 0.5-mfd capacitor, and 50-ohm wirewound rheostat.

Connections Required: Connect the equipment as shown in Fig. 156.

Procedure: Set the pulse generator for a positive-pulse output, with a pulse width of about 100 milliseconds and an arbitrary repetition rate. Vary the setting of the rheostat and observe the scope pattern.

Evaluation of Results: The critical-damping resistance is the value at which the ringing is just eliminated in the scope pattern. Note that the speaker should be mounted in its cabinet or baffle when this test is made.

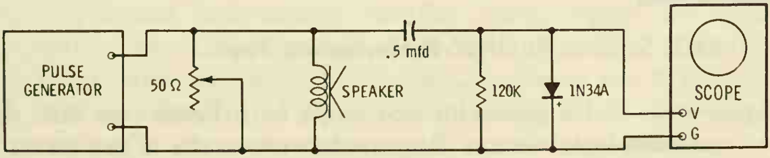


Fig. 156. Measuring the critical-damping resistance of a speaker.

OR Section Proof-of-Performance Test

Equipment: Pulse generator and scope with faster rise than the machine-logic section. Triggered-sweep scope is preferred.

Connections Required: Connect the equipment as in Fig. 157.

Procedure: Test each channel separately. Set the pulse generator to a pulse width and repetition rate that are well within the rated limits of the machine-logic section. Then, advance the pulse amplitude until a stable pattern is displayed on the scope screen. Finally, reduce the pulse width in steps, and increase the repetition rate in steps until the displayed pattern becomes unstable or disappears.

Evaluation of Results: If no pattern or an erratic pattern is obtained in the initial test of either channel, look for a defective component in the logic section. The minimum pulse amplitude required for stable operation, minimum pulse width, and maximum repetition rate should equal or exceed the manufacturer's ratings for the logic section. If waveform specifications are provided, check the distortion of the output pulse at maximum capability of the logic section against the specified waveform.

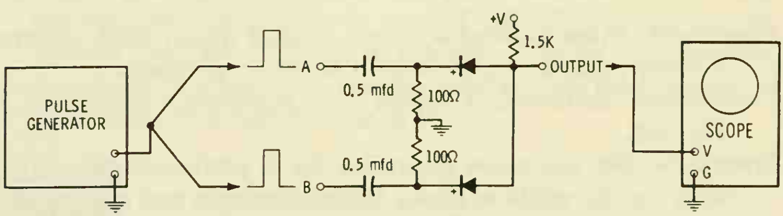


Fig. 157. Proof-of-performance test for an OR machine-logic section.

U100

AND Section Proof-of-Performance Test

Equipment: Pulse generator and scope with faster rise than the machine-logic section. Triggered-sweep scope is preferred.

Connections Required: Connect the equipment as in Fig. 158.

Procedure: Set the pulse generator to a pulse width and repetition rate that are well within the rated limits of the machine-logic section. Then, advance the pulse amplitude until a stable pulse pattern is displayed on the scope screen. Finally, reduce the pulse width in steps, and increase the repetition rate in steps until the displayed pattern becomes unstable or disappears.

Evaluation of Results: If no pattern or an erratic pattern is obtained in the initial test, look for a defective component in the logic section. The minimum pulse amplitude required for stable operation, minimum pulse width, and maximum repetition rate should equal or exceed the manufacturer's ratings for the logic section. If waveform specifications are provided, check the distortion of the output pulse at the maximum capability of the logic section against the specified waveform.

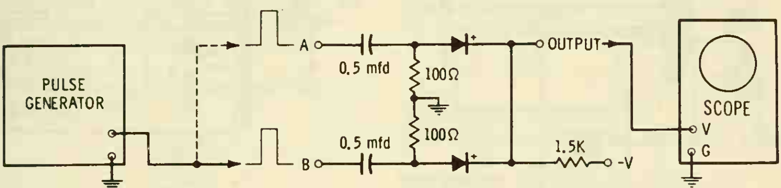


Fig. 158. Proof-of-performance test for an AND machine-logic section.

U101

To Make a Ringing Test of a Horizontal-Output System

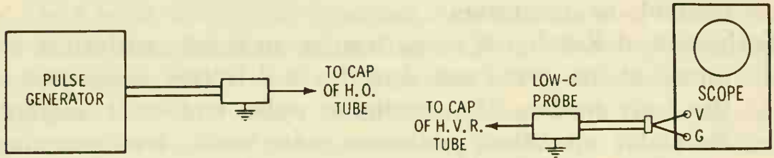
Equipment: Pulse generator, 20-mmf capacitor, and scope.

Connections Required: Unplug the caps from the horizontal-output and high-voltage rectifier tubes. Apply the pulse voltage through a 20-mmf capacitor to the H.O. capacitor, and connect the scope via a low-C probe to the H.V.R. capacitor. (See Fig. 159.)

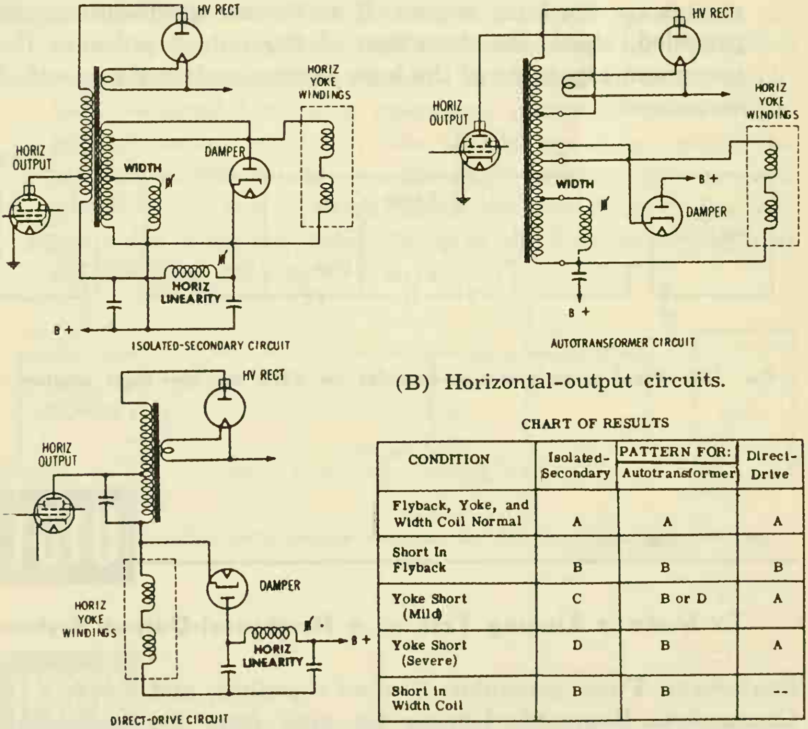
Procedure: Set the pulse generator for a 10-microsecond pulse and 1000 pulses per second. Adjust the scope deflection rate

as required to display the complete ringing pattern. (NOTE: Receiver must be turned off in this test).

Evaluation of Results: Normal and abnormal ringing waveforms for the three basic horizontal-output systems are illustrated in Fig. 159. The ringing frequency is approximately 45 kc for a normal horizontal system.



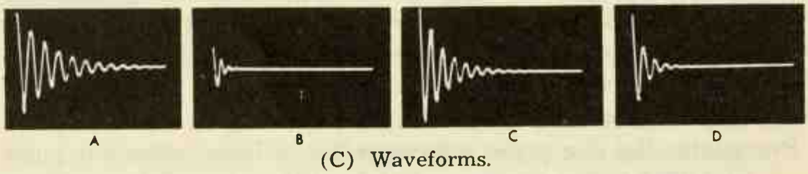
(A) Test setup.



(B) Horizontal-output circuits.

CHART OF RESULTS

CONDITION	PATTERN FOR: Isolated-Secondary	Autotransformer	Direct-Drive
Flyback, Yoke, and Width Coil Normal	A	A	A
Short In Flyback	B	B	B
Yoke Short (Mild)	C	B or D	A
Yoke Short (Severe)	D	B	A
Short In Width Coil	B	B	--



(C) Waveforms.

Fig. 159. Ringing test of a horizontal-output system.

INDEX

101 WAYS to Use Your SQUARE-WAVE and PULSE GENERATORS

by Robert G. Middleton

Television servicemen and electronics technicians are required by the nature of their work to be familiar with a large variety of test equipment. It is almost always assumed that these men have a good working knowledge of the tools of their trade. Often, however, a certain routine is developed so that each piece of test equipment performs only a limited number of tasks. The procedures worked out may not be the most efficient. Yet, a familiar routine tends to be used whenever possible as long as the results are anywhere near satisfactory.

The **101 Ways to Use Your Test Equipment** series has been written to encourage servicemen and technicians to explore the total possibilities of their test equipment. Each book takes a major unit or a group of related pieces of equipment and shows the ways it can be used—some conventional, some unusual and imaginative. Test setups, procedures, and results are described and illustrated in detail.

101 Ways to Use Your Square-Wave and Pulse Generators describes basic tests for RC circuits, audio amplifiers, video amplifiers, inductive circuits, TV IF amplifiers, RF-IF amplifiers, stereo FM units, and RC-coupled amplifiers. It covers each test that can be made and shows waveforms which should be seen on your scope for each test or measurement. The uses for the square-wave and pulse generator range from the most basic to the more involved. Each explanation is concise and easy to follow, with amplifying notes added when further explanation is needed.

Every serviceman, technician, and experimenter should have the complete series of **101 Ways to Use Your Test Equipment** books on his reference shelf to answer questions regarding the possible uses of test equipment and to supply the best procedures for achieving the desired results.

ABOUT THE AUTHOR

Bob Middleton, one of the few full-time writers in the electronics field, is widely known for his many books and articles on servicing and test equipment. Even though he has many years of experience in the troubleshooting of equipment, Mr. Middleton is not content to rely on this experience alone. Much of his time is spent in his own well-equipped laboratory—trying to find the answer to a confusing symptom or seeking new and better ways to service equipment or use test instruments.

Mr. Middleton is the author of nine other volumes in this series; seven volumes cover the sweep generator, oscilloscope, VOM and VTVM, signal generator, ham test equipment, hi-fi test equipment, and color-TV test equipment, and two volumes encompass additional uses of the oscilloscope and VOM and VTVM. He is the author of many other helpful test-equipment and servicing books published by Howard W. Sams & Co., Inc.

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